Introduction and Evaluation of Teleprotection Systems in Micro-Grids

Mohammad Reza Miveh and Sohrab Mirsaeidi

Abstract*— A micro-grid is an aggregation of electrical and heat loads and small capacity micro-sources operating as a single controllable unit at the low or medium voltage level. Nowadays, digital telecommunications have been used in many industrial applications which micro-grid protection has also been benefited. Occurred challenges in distribution network caused by micro-grids presence, telecommunication and distribution engineers failure in recognizing the protection schema requirements and telecommunication networks restrictions always have made problems in implementation and utilization of the protection schema. In this paper, in addition to introducing types of telecommunication technology and protection system, problems existed in applying the digital telecommunication network is also evaluated for protection purpose in micro-grids and some points which a schema should consider for teleprotection system to make improvement and dependability is also explained.

Index Terms*— Micro-grid, Protection, Teleprotection, Telecommunication.

I. INTRODUCTION

Due to the increased concern over global climate change, the demand for clean sustainable energy sources has increased greatly [1]. Therefore, power industry approaches continuously towards distributed generation technology. A proposed solution to integrate high penetration DG sources is to use micro-grids.

A micro-grid is defined as a low to medium voltage network of small load clusters with Distributed Generation (DG) sources and storage [2]. In general, a micro-grid can operate in both the grid-connected mode and the islanded mode where the micro-grid is interfaced to the main power system by a fast semiconductor switch called Static Switch (SS) [3]. It is essential to protect to micro-grid in both grid connected and the islanded modes of operation against all type of faults [4].

Micro-grid protection has been faced to some challenges because of changes in amplitude and direction of fault current in both grid-connected and islanded mode. Mainly changed characteristics of fault response and effects of micro-grids on overcurrent protection have been surveyed in [5-10]. Several methods have been proposed in order to protect micro-grids so far.

Many proposed protection schemes has applied teleperotection system to protect micro-grid in two grid-connected and islanded modes. These systems implement the mentioned protection schemes by receiving the data from sensors and processing them based on the protection function defined for them.

For implementing of the protection scheme, signals and measured values, or related reports must be sent to the remote side by the protection system. According to telecommunication environment, teleprotection system transforms these information to the appropriate forms and this transformation is opposite in receiver side.

As shown in Figure 1، teleprotection system is an interface between the protection system and the telecommunication devices. Therefore, it includes the segments which prepare inputs and outputs based on this equipment. In general, telecommunication system is divided into three parts:

- Protection system interface
- Processing and making decision
- Telecommunication system interface

Telecommunication system can be used as an integrated form in the protection system or in the telecommunication terminal or as an independent device.

Different kinds of telecommunication environment such as Power Line Carrier (PLC), fiber optic, microwave, wireless technologies have been used to micro-grid protection. Thus, as regard as the capacity and available band width, type of telecommunication interface is determined for teleprotection system. Thus, teleprotection systems are proposed by different kinds of analogue telecommunication (such as, high frequency and audio band) and digital (such as optic interfaces, 2Mbps (G.703.6), 64kpbs (G.703.1)) and it is used to provide an appropriate interface according to the condition of the telecommunication environment. It is to be noted that, telecommunication services need a high speed (with the transmission time for about 10 milliseconds) and high availability network.

Currently, various telecommunication environments have been used to micro-grid protection. Therefore evaluation of existing problems in these environments which leads to lack of using micro-grid teleprotection system side the digital telecommunication systems can help utilize them appropriately.

In the paper, in addition to the introduction of the telecommunication technologies used in micro-grids protection, different types of protection systems and critical parameters in these systems also have been evaluated. Moreover, in order to improve these parameters, existing problems in using teleprotection systems in digital telecommunication networks have been analyzed.

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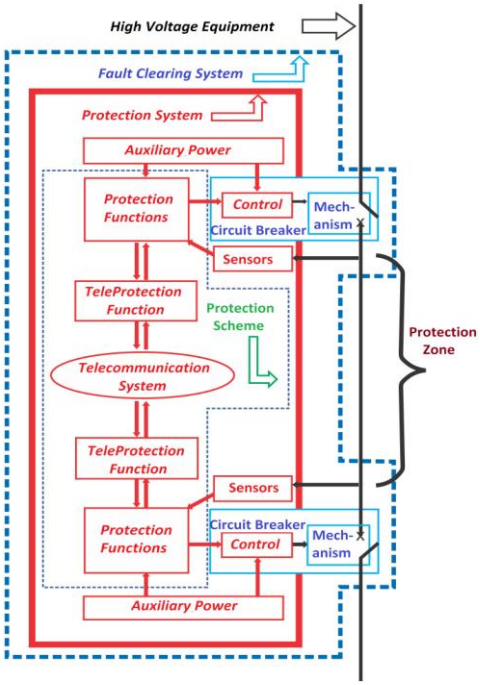

Fig.1. Fault detection and clearing mechanism in protection system.

II. TELECOMMUNICATION TECHNOLOGIES USED IN MICRO-GRID PROTECTION

Telecommunication is the transmission of information over significant distances to communicate. Some of telecommunication technologies types accomplish with their advantages and disadvantages have been summarized in the following parts:

- Distribution Line Carrier (DLC)
- wired environment
- Wireless environment

A. Distributed Line Carrier (DLC)

Using the power transmission lines as a telecommunication environment has been considered by power industry because of their various advantages. The most important advantages of using DLCs is using micro-grid cables that as well as removing the cabling problems, remote problems and extension of control points micro-grid also are not proposed.
It is to be noted that if a fault occurs within micro-grid, such telecommunication environments will face open-circuit problems. In other words, if there is a breakage and fault occurrence problem, telecommunication environment will be disconnected. Consequently, using this method with reclosers, switches, sectionalizer, and locating the breakage in circuit is impossible. Another disadvantage of the method is the number of channels and low quality of telecommunication signals.
In [11], in order to protect micro-grids against the fault, PLC has been used. PLC systems are one of the most important telecommunication systems in power industry.
PLC technology has been used for communication and protection in substations lines since the late 1920s [11].
In transmission and distribution applications, as well as in some low voltage utility applications such as automated meter reading, frequencies of 30 kHz to 500 kHz are typically used [12].
In broad band power line and in home local area power line network applications, frequencies well above 1 MHz are used with data rates up to 200 Mbps [13]. Digital PLC modulation techniques such as orthogonal frequency division multiplexing (OFDM) allow good bandwidth utilization, ability to cope with interference and multipath effects, and provide high data rates in excess of 100 kbps [14].
Although PLC technology is one of the most important telecommunication systems in power industry, it is not evaluated based on the level of magnetic field radiation. Studies show that level of magnetic field radiation around the high voltage lines is caused by high PLC signal carrier. In conclusion, as regard as the adjacent of PLC frequency band with the radio bands, there is a possibility of disturbance in them. There are different kinds of software for modeling the PLC radiation levels, such as EZNEC PRO2 which models level of radiation caused by the wire carrying current in frequencies from 100 kHz to 50 MHz.
Figure 2 and 3 illustrate the diagram of gain increasing of PLC signal radiation and the radiation pattern around the wire carrying current as an antenna simulated in various frequencies in this software respectively. As shown in Figure 3, radiation emissions from network lines have been decreased from low frequency to high frequency [15].

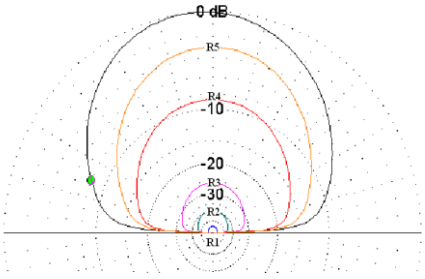

Fig.2. Diagram of gain increasing of PLC signal radiation

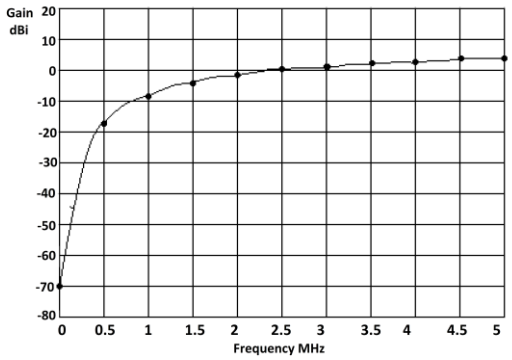

Fig.3. Radiation pattern around the wire carrying current

B. Wired Environment

In [16] some relays which contains the fiber optic and Ethernet communication link have been used for micro-grid protection. Fiber optic cables have had much progress so far. Table 1 lists the total characteristics of the optic fiber [17].

Due to the high capacity of the channel and complete security than electromagnetic interference and disturbance, Prediction of fiber optic cable will be suitable and using it makes differential protection possible. Some disadvantages of the fiber optic cable can be referred to its high price and requiring to special skills and test because of its modern technology.

C. Wireless Environment

Wireless methods include Very High Frequency (VHF) radio, Ultra High Frequency (UHF) radio, spread-spectrum radio and etc, which contain the highest range of potential to protect and control micro-grid, because they can carry out the telecommunication anywhere and at low cost. In [18], an islanding detection method is proposed based on the angle difference between power system and distributed generation with the application of synchronized measurement technologies.

According to Figure 4 in order to implement the islanding detection algorithm has been used Global Position System (GPS), in addition to the spread-spectrum radio has been introduced as an appropriate solution in sub-transition voltage level to interconnect protective relays [17].

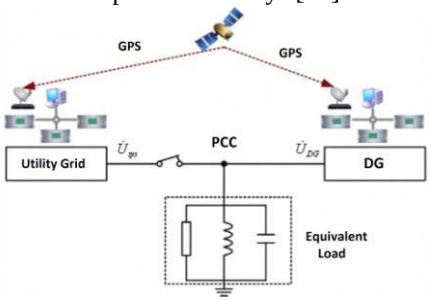

Fig.4. Islanding detection based on angle difference

Spread-spectrum radio is a good solution for sub-transmission line protection. If a tower for elevating the antenna is not required, the cost of a spread-spectrum radio system is approximately $4000 (U.S.) per line terminal (including installation). Once the system is installed, there are no additional recurring costs, such as license fees. The radio channel is physically independent from the protected line, and all of the radio equipment except the antenna can be installed in a protected enclosure.

Spread-spectrum radios use multiple frequencies in the 900 MHz and 2.4 GHz license-free ISM band to provide a point-to-point connection. Another radio using the same frequency at the same time may interfere with the signal; however, the spread-spectrum system spends a very short time at each frequency within the band. Frequency interferences typically cause very short periods of channel unavailability.

Table I, summarizes the main characteristics of spread-spectrum radio channels.

Table I. Communications channel comparison

	spread-spectrum radio	Direct Fiber-Optic Cable
Channel Unavailability (Typical)	0.0003	Very Low
Longest Failure (Typical)	1 s	Very Short
Cost (10 km, Two Terminals)	$8,000 (U.S.)	$150,000 (U.S)
Communications Delay	4 ms	0.1 ms
Data Rate	115.2 kbps	4 Gbps

III. CLASSIFICATION OF TYPES OF PROTECTION SYSTEMS

Protection systems are divided into command systems (state comparison protection schema) and analogue comparison systems based on the type of the data which they are transmitting.

In command systems, the Status of protective relays can be exchanged at two ends of a line. Given that these commands only contain data related to status of the protection part, so they need to a narrow bandwidth [19]. This data which is in a binary command form (disconnection or connection status) is changed into transmittable signals by protection system. Permissive Overreaching Transfer Trip (POTT) in directional comparison protection can be mentioned as a method of command systems.

In protection system, analogue comparison system type, measured analogue values in two protective line ends are compared together. So in each line end, measured instantaneous values of the remote side are also needed. This data can be transmitted into the remote side in the form of an appropriate telecommunication link.

For correct comparing of these values, transmission delay and time changing is so important. In [16] a differential protection is proposed for micro-grid. In differential protection, measured fault currents in terminals are exchanged by telecommunication channels. It will carry out according to the data and characteristics of the received current from terminals and predicted algorithms of the differential protection.

Current data can be provided in various methods. In some methods, finally current data will be provided in phasor value or digitized current sample and in some other methods, data related to the combined three phased current is changed into the single signal, accordingly, amount of exchanged data decreases.

In modern channels, current data is separated, processed, and exchanged in separate systems in three phases. In Table II, main characteristics of the line differential protection are compared to the POTT method [19]. It will be possible to protect differential, when telecommunication channel is safe in exchanging the data in two ends.

Wide Area Protection (WAP) is also a kind of analogue comparison protection which includes number of measurement unit.

These units are sampling as a synchronized form in different points and measured values are sent to a center to make a protection commands. This method includes automatic systems of network protection in auxiliary conditions and can prevent the disturbance of the electricity system such as overload and abnormal conditions of the voltage differential [4].

These protection schemes are known as Special Protection System (SPS), Remedial Action schemes, (RAS), System Integrity protection Schemes (SIPS). Protection requirements in this type of protection, is almost like an analogue comparison method. In WAP protection large amount of data should be transmitted, but in analogue comparison system data just are exchanging between two adjacent points. In [20-22] a protection scheme has been proposed for micro-grid by WAP protection.

Table II. Comparison between protection schemes

	Permissive Overreaching Transfer Trip (POTT)	Current Differential
Operating Speed	1.5-2 cycles	1.5-2 cycles
Fault Resistance Coverage	Lower	Higher
Maximum Number of Line Terminal	15	3
Bandwidth Requirement	9.6-38.4 kbps	56-115 kbps
Loss-of-Signal Consequence	Failure to Trip	Failure to Trip

IV. MAIN PARAMETERS IN TELEPROTECTION SYSTEM

Protection system of the electricity networks are used for detecting the possible faults which occur in high voltage equipment or lines. Correct receiving of errors and rapid reaction are main conditions of these systems. In brief, the most important evaluation parameters of a teleprotection system are as follows:

- Security
- Dependability
- Trip transmission time

Which the definition of each one has come blow. Security of teleprotection system means that lines shouldn't receive an unexpected disconnection command under no conditions, even because of interference or noise conditions. Also if those commands which are transmitted were not received by receiver in a specified period, they are considered to be lost. This parameter is proposed as dependability.

Transmission time of the disconnection command is an another important parameters in teleprotection system which includes the spent period from command input to period of changing command output status and this period should be so low.

It is noteworthy that these three parameters are related together and an appropriate value of them is selected based on the teleprotection needs and one improvement would drop another. For example, increasing the period of transmission commands in a system leads to security increasing and dependability decreasing.

V. PROPOSED PROBLEM IN USING MICRO-GRID TELECOMMUNICATION SYSTEM IN DIGITAL TELECOMMUNICATION NETWORKS

Today, data transmission and IP, TDM based- digital telecommunication networks have been entered in all fields of technology and has affected on many of the technical principles related to industries, which in protection power system, and specially protection of micro-grid, these portions are also gone. Accordingly, modern telecommunication networks standards have been developed to transmit audio and data in general application, using them in teleprotection application which in terms of delay and dependability requires special consideration and more analysis.

In brief, in a digital telecommunication which parts of electricity protection system, the following should be considered in terms of performance:

- Maximum transmission delay
- Maximum protection time
- Maximum propagation time variation
- Maximum propagation time symmetry
- Availability
- Redundant

In most digital telecommunication networks in order to improve the quality of service, redundant equipment are used to protect the equipment and network.

In the failure of equipment conditions or the communication link, link will be disconnected abruptly. Thus, protection of the network or equipment in telecommunication system get active and telecommunication system needs enough time for setting, recovery, and reconnection. In this condition telecommunication channel is not available for a period of time. This recovery time depends on the network topology, type of protection and type of the equipment which is used.

The utilizer of electricity network proposes the long recovery time as a problem in using digital teleprotection network. According to the IEC 60834- 1&2, the tests which should be done on the teleprotection system to meet all equipment application in the network, include security, dependability, transmission time, and recovery time [7, 23].

As it was shown in these standards, in telecommunication system with the digital telecommunication interface, Security against the failure to receive unwanted commands, is important in both security with burst disturbance mode and security with sudden signal interruption mode.

Because in an appropriate teleprotection schema, existing backup protection and redundant will provide the security. So, this problem can be solved by using an appropriate backup protection and redundant system with independent telecommunication environment.

VI. CONCLUSION

Development of micro-grid technology has created an opportunity for using micro-sources in distribution systems. Micro-grid presence caused changes in coordination among protection devices, which made it essential to apply modern techniques to protect these networks.

The use of the teleprotection system is one of the techniques that are used for preventing the equipment failure and extension of the failure in micro-grid. In this paper, types of applied technologies in micro-grid protection and protection system used were evaluated. Also, the complicated protection scheme and existing problems in using teleprotection system were surveyed.

As it was proposed in this paper, using the independent redundant protection system and telecommunication environment can provide required dependability for the network in telecommunication recovery time and in path switching, and telecommunication devices. But delay problem and its changes in channel activation time or in the communication path of the digital telecommunication network should be considered.

REFERENCES

1. Nikkhajoei H, Lasseter R. H, “Micro-grid Fault Protection Based on Symmetrical and Differential Current Componsents”, Power System Engineering Research Center, 2006.
2. European Smart Grid Technology Platform, Vision and Strategy for Europe’s Electricity Networks of the Future, EU Commission, Directorate-General for Research, Information and Communication Unit. Brussels, Belgium, 2006.
3. C. Green and J. D. McDonald, “Modeling and analysis of fault behavior of inverter micro-grids to aid future fault detection,” in Proc. IEEE Int. Conf. Syst. Eng, pp. 1–6, 2007.
4. Ming Sun, Juan Y, DENG B, “Analysis of Impact of DGs on Line Protection of Distribution Networks”, Power System Technology, vol, 33(8), pp, 104-107, 2009.
5. Chao Y, Gang W, Xiang-Jun Z, “Protection technology for distributed generation systems”, Power System Protection and Control, Vol, 37(2), Jan, pp: 99-105, 2009.
6. Shen L, “Reaserch of the protection of the distribution network with distributed generator”, Tianjin, Tianjin University, 2007.
7. Zhong W, “Study on Relay Protection in Power Distribution Network with Distributed Generation”, Urumchi, Urumichi University, 2009.
8. Lasseter R. H, “CERTS Micro-grid”, IEEE International Conference on System of Systems Engineering, April 16-18, 2007.
9. Mohammad Reza Miveh, Mojtaba Nouri, Sohrab Mirsaeidi, Hossein Refahi and Arup Sinha, "Distributed Generation Placement to Maximize the Loadability of Distribution System Using Genetic Algorithm", *ICECT*, Kanyakumari, India, 2012.
10. Conti S, Raiti S, “Integrated Protection Scheme to Coordinate MV Distribution Network Devices,DG Interface Protections and Micro-grid Operaion”, IEEE Clean Electrical Power, International Conference on, 2009, pp. 640-646, 2009.
11. Anish Prasai, Yi Du, Andrew Paquette, Edward Buck, Ronald Harley, and Deepak Divan “Protection of Meshed Micro-grids with Communication Overlay”, IEEE International Conference on System of Systems Engineering, April 64-71, 2010.
12. "IEEE Guide for Power-Line Carrier Applications," IEEE Std 643-2004 (Revision of IEEE Std 643-1980), vol., no., pp.0_1-134, 2005.
13. Atheros Communications. "White Paper - Powerline Communications Performance Testing," Accessed June 20, 2010, http://www.atheros.com/pt/plc/downloads/whitepaper_PLCPerformanceTesti ng.pdf.
14. PRIME Alliance. “MAC Spec White Paper,” Accessed June 27, 2010, <http://www.prime-alliance.org/portals/0/specs/
15. Ed Hare, "Power Lines as Antennas from 100 kHz to 50 MHz", July 2003, www.arrl.org.
16. E. Sortomme, S. S. Venkata, and J. Mitra, "Micro-grid Protection Using Communication-Assisted Digital Relays," IEEE Transactions on Power Delivery, 2010.
17. R. Moxley and K. Fodero, “High-Speed Distribution Protection Made Easy: Communications-Assisted Protection Schemes for Distribution Applications,” Proceedings of the 31st Annual Western Protective Relay Conference, Spokane, WA, October 2004.
18. Yongli Li, Zhiqian Bo, Klimek, A. “Design of protection and control scheme for micro-grid systems”, IEEE International Conference on System of Systems Engineering, Universities Power Engineering Conference (UPEC) 1-4 Sept. 2009 , 2009.
19. M.R. Miveh, M. Gandomkar, S. Mirsaeidi, H. Nasiban, “Micro- Grid Protection by Designing a Communication-Assisted Digital
20. Relay”, American Journal of Scientific Research, Isuue 51, Feb.
21. 2012, pp. 62-68.
22. Cigre, WG D2.26, “Telecommunication Service Provisioning and Delivery in the Electrical Power Utility”, TB-461, April 2011.
23. Chao Y, “Novel Protecion Methods of Distributed Generation System”, Changsha, Changsha University of Science & Technology, 2009.
24. Xia L, Yu-ping L, Lian-he W, “New Fault Region Location Scheme in Distribution System With DGs”, Transactions of China Electro Technical Society, vol. 23(11), Nov, pp. 139-145, 2008.
25. Xia L, Yu-ping L, Lian-he W, “New Current Protection Scheme Considering Distributed Generation Impact”, Automation of Electric Power Systems, vol. 32(20), Oct, pp.50-56, 2008.

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