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New protection principle for smart grid with renewable energy sources integration using WiMAX centralized scheduling technology

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ABSTRACT

The Benefit integration of distributed energy resources (DER) into distribution grid or large-scale renewable energy sources (RES) into transmission systems faces a considerable challenge to existing power system protection. In such case the coordination system of the protection is failed completely. The features given in the current standard of IEEE 802.16 solve the problem between the local and wide-area networks by providing an advanced system for metropolitan environments. This feature can be addressed to solve many traditional protection problems. The paper produces new protection solution to identify the faulted zone properly using IEEE 802.16 wireless protocol. Selecting 802.16 as a mesh mode will help allocation of minislots handling the centralized and distributed scheduling mechanisms. This is the first time of applying such technology in the protection system. The idea has the feature of protecting the grid as "*Unit-Area*" instead of "*Multi-Area*". Principle of one protected zone instead of multi protection zones is used. The system consists of a base station, switching center and Intelligent Electronic Devices (IEDs). An accurate and proper decision is obtained based on shared information rather than stand alone relay decision.

1. Introduction

Renewable Resources penetrations are fast spreading and will play an increasingly vital role in the future power supply system. Plug-in Electric Vehicle (PEV) with Vehicle-to-Grid (V2G) potential is becoming reliable and flexible resources for energy balancing under varying energy supply and demand scenarios [1]. To increase the system reliability, sustainability, affordability the modern power grid should become enough smarter [2]. There many key factors can change the power system characteristics that can be critical to be recognized because of the progress of the smart grid development around the world. This matter is very obviously in the distribution levels due to penetration of the microgrid, energy storage and renewable sources [3]. However, they raise a number of challenges, including a need for new protection techniques. Transmission system with Renewable Resources penetration protection will be independent for high current, direction of the power flow, unbalanced load and intermittent generators on the nodes [4]. The traditional protection for the feeder depends on the short circuit current values. When one of sources is added, the power can flow in many directions through the protective relays that make the feeders like a transmission line [4].

The target MicroGrid should support the integration of renewable energy systems, such as wind and solar, which will have direct impacts on the performance of the grid [5]. Such effects can be limited for the low voltage while it has potential in case of medium voltage level, as illustrated in Fig. 1. The currents can flow in different directions; see relays 1, 2, 3 and 4 on the figure. The existing protection schemes will not be able to be adaptive due to the different ways of the current flow due to different operations. Renewable resources penetration on the grid will change the system coordination and the normal protection schemes will fail completely. Applied protection schemes based on standalone decision will not be able to handle such complexity of natural of grid. New innovative protection scheme for protecting the smart gird based on data sharing is needed.

The digital current differential relays offer perfect and selective protection for transmission lines. They have many features over distance relays. These relays have better sensitivity in case of faults with high resistance, almost all the line zone is protected, and have better performance in case of single pole tripping [6]. The possible use of wireless communications in substations can satisfy the features of

Abbreviations: PEV, Plug-in Electric Vehicle; V2G, Vehicle-to-Grid; IEDs, Intelligent Electronic Devices; MAS, multiple address radio; TDD, Time Division Duplexing; MAC, Media Access Control; FHSS, Frequency Hopping Spread Spectrum; DSSS, Direct Sequence Spectrum; CSMA, Carrier Sense Multiple Acess; FDD, Frequency Division Duplexing; CPS, Common Part Sublayer; DL-MAP & UL-MAP, Maps of Multiple Access downlink and uplink; MSH-CSCH, Mesh Centralized Scheduling; MSH-CSCF, Mesh Centralized Scheduling Configuration; MSH-DSCH, Mesh Distribution Scheduling; DCF, Distributed coordination function

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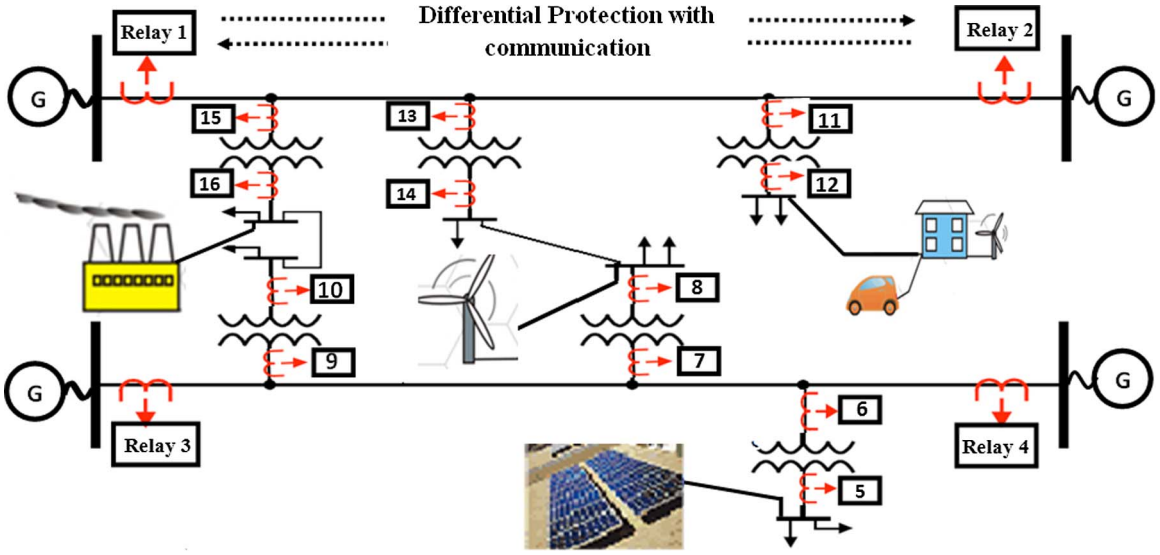

Fig. 1. Renewable resources and bidirectional flow.

differential relays. Some applications can use the technology of wireless communications. They could be used safely, reliably, and securely. A proper security is highly needed for data exchanges while they have time sensitive [7]. During normal operation the tapped transformers draw some load current, as given in Fig. 1. An error signal will be appeared in the differential circuit due to total load current. The power transferred from the substation is very high if compared by the load current drawn from tapped points. This is the reason of restraining the differential relays by bias current. However, as the number of taps increases, The load current can be high due to differential zone leaking [8–11]. As explained above the traditional protection schemes with communication channel will not be able to protect complex smart grid with multiple renewable sources at the transformer points. To improve the protection, control, planning, and analysis of operation, maintenance and outage restoration many communication techniques are applied. The techniques assist the engineers to change operation, access real time, historical data for the relays and also the maintenance testing [12]. A current differential protection scheme for protecting active distribution networks is given in [13]. The proposed differential principle can be changed according to configuration and fault characteristics of active distribution network. A current only directional overcurrent relay was given in [14] to protect distribution automation system. Some feeders techniques based on impedance principle in distribution networks are given in [15].

The unexpected penetration of the renewable resources will change in the protection setting resulting in false operation for the protection schemes. Communication between relays located on the different points on the smart grid will increase relays selectivity and insure accurate decision for the relays even during penetration of renewable resources. Selecting protection schemes suitable with communication between relays also should be carefully selected. In the conventional schemes based on differential relays a misoperation is mostly occurred due the differential signal. The reason is the current balance measured by the differential relays does not include the tapped current and so the faults occurred on the tapped transformers located on the low voltage side will create this differential signal. A new idea such proposed here can solve easily this problem. The interconnection of renewable resources as shown in Fig. 1 will alternate the system characteristics, while the distribution systems are conventionally designed as a passive network. This tends to that the renewable resources integration is not valid. There are many challenges that include protection coordination and changing in the protection settings, while the protection schemes are based on differential fixed setting signal. Fig. 2 shows the tradition zone of operation used for this system.

The relay selectivity must be improved and also the interruption of loads connected to healthy feeders should be minimized. And to achieve that, the relays based on wireless technology should be well coordination. The paper presents new protection philosophy to identify the faulted zone properly using IEEE 802.16 wireless protocol. The idea has the feature of considering the configuration studied as one zone instead of multi zones, see Fig. 2. Now, the electric substations needs for new wireless technologies to face the growing in the physical security and complexity of communication networks. These technologies should be carefully selected to cover needs of the protection and power applications [4]. The wireless technology can be applied to solve many of the protection problems and many of the shortcoming points that are still embedded for transmission lines protection. Such high system specification will be very appropriate for the smart grid protection in case of integration of DER and RES into distribution grid and Transmission systems.

The paper presents an explanation of the proposed protection scheme using WiMAX architecture. It explains also the online study of the data reading, data storing, synchronization on process, directionality estimation, and sharing information based on adaptive coordination of the directional relays' status.

2. Sensor networks communication and IEEE 802.16-WiMAX architecture

The IEDs can easily exchange the data and information through wireless network. Such information and data help the IEDs to handle correct decision. The radial systems do not have bi-directional flows. Transmission system with Renewable Resources penetration protection should not depend on high-fault current, directional of power flow, unbalanced load and intermittent generators on the buses. To minimize the loads interruption and improve the selectivity of the protection schemes the wireless technology is used. By this way the system coordination is well established. The paper presents new protection philosophy to identify the faulted zone properly using IEEE 802.16 wireless protocol. The idea has the feature of considering the configuration studied as "***Unit-Area***" instead of "***Multi-Area***". The system is based on base station, switching center and Intelligent Electronic Device**s** (IEDs). An accurate and proper decision is obtained based on shared information even with distributed generation penetration.

The communication architecture for sensor networks is outlined. Many relays that perform sensing and measurements can be deployed.