ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

ADAPTIVE SMART CENTRALIZED SUBSTATION PROTECTION SYSTEM THROUGH SELF-HEALING

P.Hemeshwar Chary [1], N.Santosh Kumar [2]

[1] Assistant Professor, Dept of EEE, CBIT(A), Gandipet, Hyderabad, Indiahemeshwarchary@gmail.com

[2] Assistant Professor, Dept of EEE, CBIT(A), Gandipet, Hyderabad, India nirudisantoshkumar@gmail.com

ABSTRACT

This paper first presents a review of the current technology in power system protection and control, including the protective relays, local controls and system controls. Then, this paper presents a couple of typical scenarios to illustrate the possible problems with the existing technology. Next, this paper proposes the vision of a self-healing protection and control system based on real-time, look-ahead simulation such as in every 5 to 15minutes. This is different from the present technology such as Special Protection Scheme, which is based on a large amount of offline simulation runs. Modern power system is more flexible and complex than the conventional power system. From a reliability point of view it is important to identify and isolate the fault as fast as possible from the neighboring zones. This paper proposes protection solutions for smart grid. In particular, the main focus of this paper is on three different protections namely overcurrent protection, transformer protection, and directional overcurrent protection.ETAP software has been used to verify the system operation.

KeywordsSelf-healing, microgrid control,distributed generation,Substation Protection, microgrid, power system

1. INTRODUCTION

The present technology in power system protection andcontrol has been considered unsatisfactory to provide arobust, fast, and efficient support to system-wide disturbance.On one hand, the present protection and control systemsconsist of many devices across the system and they lack asystem-wide coordination scheme. This sometimes can worsenthe system conditions during emergency. On the other hand,settings of protection devices and parameters of controlsystems are pre-determined based on off-line simulation resultsand remain fixed regardless of system operating conditions.The latest development in communication, control andcomputing systems has attracted increasing interests in powerengineering community to explore possible solutions to build more robust power systems. Such systems should be ableto fully utilize the real-time, system-wide information,dynamically adjust the protection and control, and effectivelyrestore the system to normal conditions. With this vision, theconcept of a self-healing protection and control system isProposed and discussed in this paper. Different from the previous discussions in, this paper presents a moredetailed approach about a possible implementation of a self-

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

healingprotection and control system. In recent years, there has been a tremendous increase in thedeployment of renewable energy resources in electrical powersystem. This is because of increased environmental concernsand global climate change. Europe and many other countrieshave started to construct smart grids. They consider this as animportant part of their national power strategy. Today,smart grid has named as the next generation of the power gridwhich uses two-way communication of electricity and digitaltechnology to supply electricity. Smart grid improves thereliability and reduces the peak demand. It also helps to increasethe energy efficiency along with the environmental benefitsgained by such efficiency. However, it poses a number ofchallenges to electrical engineers in all aspects especially indeveloping appropriate protection solutions because of thebidirectional power flow capability.Conventional power system uses various protective relaysto isolate a device or a system during a fault. However, in somecases if the relay is over sensitive it may cause unexpected tripswhich could cause cascading failures. In this paper,self-healing is applied to improve the reliability to avoid falsetrips thereby preventing the disturbances from spreading acrossthe entire power grid. In a smart grid, the computer andcommunication systems will send corrective measures in lessthan half a second in the case of a fault thereby triggering thecircuit breaker to isolate the faulty line, and this prevents other lines from being damaged. Smart grid was integrated transducers technologies, developing control strategies, and modern communication to the power grids to make the complete vision into reality. Fig.1 declares a guide of smart grids technology. As seen in this figure, its grid consists of three parts including power grid, intelligent systems, and communication systems. Distribution generations (DG) were provided many advances including improved reliability, and enhance security as well as inexpensive electricity. In the smart grid, the impact of faults on customers was minimized by an instantaneous identification of the fault location, correct decisions, system restoration of healthy parts, and recovery of the system to normal condition.

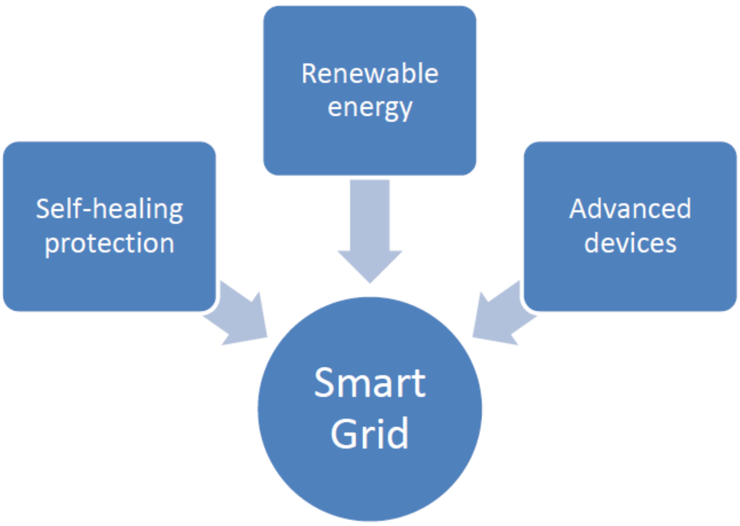

Figure 1: Smart grid idea

Self-Healing is the capacity of electrical distribution systems to automatically restore themselves if a permanent fault occurs. Depending on the level of automation, self-healing schemes isolate permanent faults in certain zones of the grid and restore the electrical service

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

to other zones as soon as possible and with minimal human intervention. After a permanent fault has been located, optimal restoration minimizes the number of interrupted users and guarantees that the new topology maintains the system's constraints within their limits. A truly automated self-healing scheme is only possible within a smart grid context, as remote-controlled switching devices are used to isolate faulty zones and transfer loads to alternative sources, and direct load control devices installed in specific nodes of the system, are used to de-energize nonvital loads (i.e., remote load-shedding)

2. LITERATURE SURVEY

Different methods were implemented to locate the fault in the smart grid such as apparent impedance [1]. In [2], the thee-phases circuit analysis was measured such as the local voltage and current measurements in the substation. The fault location algorithms were obtained after iterative solution or complicated three-phase circuit equations. These equations were described as the steady-state fault condition. In [3], the earth fault locations were depended on the equality between the computed sequence components of the current at the fault point at different load conditions. Traveling wave methods were discussed in [4]. These methods are based on the frequency component of traveling waves for faulted voltages. In [5], the proposed method was calculated as the fault location in the radial smart grid with different laterals. After the fault has occurred, high-frequency transients were generated and propagated outs into both sides. The fault location method was estimated based on the time interval between the traveling waves and the time reflections arriving from the fault location. On the contrary, the traveling wave method was affected by the presence of laterals and load taps [6]. Artificial intelligent based methods such as an artificial neural network (ANN), Fuzzy Logic (FL), Expert System (ES), and hybrid method were discussed in [7]. Both methods were used post network status, list of tripped breakers, protection alarms, and the conventional event log.In [8], sectionalized re-closure, midpoint re-closure, and tie-point re-closure were integrated with IED for monitoring and protection. The re-closure has detected the fault, isolated the fault section, and restored the power to the healthy part of the smart grid. The re-closure was connected to the grid through a radio or GSM module based on IEC61850 protocol capabilities. Three different FDIR approaches using a loop control scheme, IEC61850 peer-to-peer, and a decentralized control-based substation were proposed. In [9], the reliability of the network was enhanced by increasing the number of re-closer. The re-closer was communicated by using a high-speed Ethernet communication system through fiber optics in the SCADA system. This method was enhanced the restoration time for the healthy section. In [10], advanced communication technology was used to manage the stored information from a smart grid by using IED devices and smart metering. This technology enhances the reliability and starts the self-healing features. Several approaches were proposed in a centralized by including heuristics, expert systems, metaheuristics, and mathematical programming [11]. The expert's knowledge and experience were translated into programming logic to solve the problem in [12]. In [13], the proposed reconfiguration algorithm was introduced to reduce the loss of service restoration based on switching indices. These indices were provided by using the branch voltage drop, line constants, and weight factors. Integrated load curtailment (LC) for serving customers in the restoration plans was proposed in [14].

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

This algorithm was based on heuristics rules by using the post-fault power flow calculations. The input information is the number and percentage of the LC candidate which is predetermined. In [15], the service restoration method with a minimum number of switching operations was proposed. Expert system-based techniques were proposed in [16]. This system was involved in the restoration of the Expert's knowledge as rules (IF-THEN statements). In [17], developed an Expert system combined with an objective-oriented programming technique were proposed for solving the restoration issues. Different strategies such a single grouping and multi-grouping were utilized by dividing the outage region into single or multiple groups based on feeder margins, branch points, and available tie switches in [18].

3. PROPOSED SYSTEM

3.1Self-healing smart grid

To achieve self-healing in a power grid, the system should have sensors, automated controls, and advanced software that uses real-time distribution of data to detect and the isolate faults and to reconfigure the distribution network to minimize the poweroutage and customer impact [15]. One of the key objectives of a self-healing grid is to improve the system reliability. This canbe accomplished by reconfiguring the CBs and relays andreclosers installed on the distribution feeder to quickly isolatethe faulty section of the feeder and re-establish the service to asmany customers as possible from alternate sources or feeders.Self-healing solutions typically need to reconfigure the systemwithin one to five minutes. To accomplish this high bandwidthcommunications may be required.Self-healing is the property that enables a system to perceiveif a system is not operating correctly and, without humanintervention, make necessary adjustments to restore the systemby itself to normality. Self-healing usually refers toreconfiguration, load shedding, and controlling the generators'output powers. Self-healing actions are a multi-objective,nonlinear optimization problem with a number of constraints.Advanced algorithms need to be developed using artificialintelligence techniques and multi-agent systems to solve theseproblems. Restoration problems are much sophisticated insmart grids due to the challenges such as bidirectional powerflow; mesh connected topologies, and limited capacities ofdistributed energy resources (DERs).

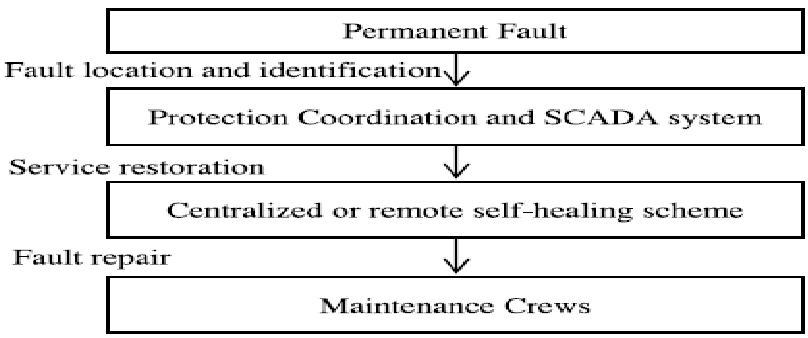

Figure 2: Smart grid protection flow

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

The self-healing scheme is activatedwhen a permanent fault has been located and identified bythe protection scheme and the supervisory control and dataacquisition (SCADA) system. This is, when the coordinatedoperations of the protective devices installed along the feeders,or the meters connected to a SCADA system, locatea faulty zone, the self-healing scheme is deployed to immediatelydetermine the set of restoration strategies to be carriedout [2]. After the permanent fault has been repaired by maintenancecrews, the distribution system is returned to its originaloperation state and the self-healing process ends.A self-healing scheme can follow two approaches dependingon the decision maker. The first is a remote approach,which is based on the ability of the protective and switchingdevices to communicate and coordinate control actions amongthemselves. Currently, these features are incorporated intointelligent electronic devices (IEDs) that control the reclosingand switching mechanisms, or it can be programmed intoexisting equipment [3]. Although this remote approach is suitablefor specific loads that has to be restored very quickly,such as in hospitals, if not well coordinated with the dynamicsof the load and the existing protecting equipment, a totallyremote self-healing scheme applied to an entire distributionnetwork could cause nuisance tripping, constraints violations,or power quality complaints. The second approach is calledcentralized self-healing [4]. In this approach, all of the electricaland operative system information is gathered by theIEDs in the field and sent by the SCADA system to the controlcenter where the self-healing scheme is installed. Then,if there is a permanent fault, the self-healing system executesa set of restorative actions. Thus, the objective of thispaper is to develop a methodology based on mathematicaloptimization in order to efficiently determine the best restorativeactions to be taken after a permanent fault is locatedin the system, considering the electrical and operationalconstraints.

3.2 self-healing protection and control system

We propose thefollowing vision of a future Self-Healing Protection andControl System, as shown in Figure 3.

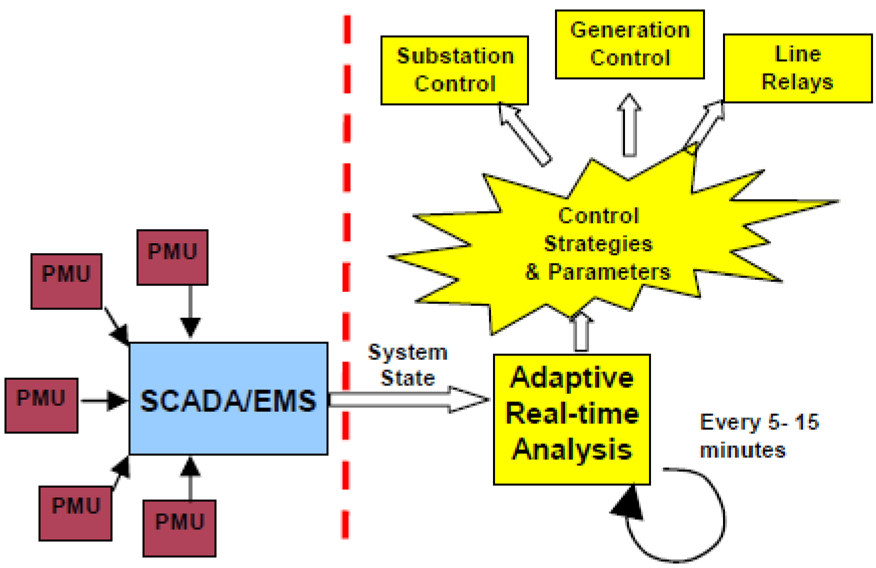

Figure 3: The proposed self-healing protection and control system

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

In Fig. 3, the SCADA/EMS system collects data fromPhasor Measurement Units (PMU) due to the expected successand large-scale deployment in the near future. Then, the EMSsystem will give an estimation of the present system state. Asshown in the left part in Figure 3, this is similar to the presenttechnology.The difference is the new function shown in the right part in Figure 3, where an adaptive real-time or look-ahead analysisshall be performed every 5 to 15 minutes. The analysis willgive some recommendation of possible updated controlstrategies and parameters, especially in the event ofcontingencies. That is, the system shall know what actions totake based on the present system condition in the case that acertain contingency does occur in the next 5 or 15 minutes.

The possible action could be whether Zone 3 backup relaysshould be adjusted based on the present system condition ornot, load shedding should be activated to enter a warning stateor not, etc. Certainly, the updated strategy and parameters shallbe delivered to the remote protective device and controlsystems. Therefore, if a contingency really occurs in the next 5 Or 15 minutes, different remote local controls should knowwhat actions to take, and these actions should be a coordinatedaction based on the real-time or look-ahead simulation.Apparently, there exist many technical gaps to implementthe proposed self-healing protection and control systems.Several challenges are summarized as follows:_ there is a lack of online coordination schemes ofdifferent protection and controls. The presenttechnology like SPS is based on a large amount of offline studies, while the proposed work requires a fast,robust approach to coordinate the controls in real time._ the present technology is mainly controlled by localsignals, while the proposed work requires the protectiverelay to respond to extensive, adaptive system signals._ The present EMS system has a state estimation functionbased on data collected from Remote Terminal Units (RTU), while the future EMS system may have a real-timesynchronized state measurement to have betteraccuracy and speed._ The present communication infrastructure is a mix oftelephone lines, Broadband over Power Lines (BPL),wireless communication, microwave, optical fiber, andso on, while the future communication infrastructureshould be fast, dedicated communication system like optical fiber such that the communication delay will beminimized. Also, communication protocol standard andQuality of Service (QoS) should be fully implemented._ the present computing technology in most controlcenters is based on sequential computing, while thefuture work may be based on dedicated parallelcomputing resources with proper prioritizing andscheduling of different real-time simulation tasks. From the simulation results, it can be seen that, whetherthe BESS unit is in themaster or the slave, the voltage of BESSunit is always kept stable and the output current changed withtheAC line and kept theDCbus line voltage stable also. It can be seen that the DC bus line isstable in 400V quickly. It can be seen thatwhen the BESS unit is in the charging state, the energy willflow into BESS fromAC line and the phase angle between thecharging state and the discharging state is 180o.The simulation and experiment of BESS chargingstate. *U*bat and *I*bat are the voltage and current of battery,respectively. From the results, it can be seen that battery canrealize from constant-current charging to constant-voltagecharging and there is no current peak.

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

4. CONCLUSION

This paper first presents a brief review of the presenttechnology of power system protection and control. Then,discussions are presented to illustrate the possible problem andinefficiency with the present technology. The vision of apotential solution, called self-healing protection and control, isproposed with discussions about the major technology gap toovercome in order to fully implement the proposed idea in thelong run. Future work may lie in research and demonstration ofthe feasibility of the proposed concept of self-healingprotection and control.

REFERENCES

[1] T. Ghanbari and E. Farjah, A multiagent-based fault-current limiting scheme for the microgrids, *IEEE Trans. Power Del.*, Vol. 29, No. 2, Apr. 2014, pp. 525-533.

[2] M. Kezunovic, Smart fault location for smart grids" *IEEE Trans. Smart Grid*, Vol. 2, No. 1, Mar. 2011, pp. 11-22.

[3] G. D. Ferreira et al., Impedance-based fault location for overhead and underground distribution systems, *in Proc. North Amer. Power Symp.* Champaign, IL, USA, Sep. 2012, pp. 1-6.

[4] M.-S. Choi, S.-J.Lee, S.-I.Lim, D.-S. Lee, and X. Yang, A direct three-phase circuit analysis-based fault location for line-to-line fault, *IEEE Trans. Power Del.*, Vol. 22, No. 4, Oct. 2007, pp. 2541-2547.

[5] M. Elsadd, N. Elkalashy, T. Kawady, and A. Taalab, Earth fault location determination independent of fault impedance for distribution networks, *in International Transactions on Electrical Energy Systems*, Vol. 27, No 5, 5 May 2017,pp. 2389-2398.

[6] S. Lin, Z. Y. He, X. P. Li, and Q. Q. Qian, Travelling wave time-frequency characteristic-based fault location method for transmission lines, *IET Gener., Transm.Distrib.*, Vol. 6, No. 8, Aug. 2012, pp. 764-772.

[7] M. Pourahmadi-Nakhli and A. A. Safavi, Path characteristic frequency-based fault locating in radial distribution systems using wavelets and neural networks, *IEEE Trans. Power Del.*, Vol. 26, No. 2, Apr. 2011, pp. 772-781.

[8] J. Sadeh, E. Bakhshizadeh, and R. Kazemzadeh, A new fault location algorithm for radial distribution systems using modal analysis, *Int. J. Elect. Power Energy Syst.*, Vol. 45, No. 1, Feb. 2013, pp. 271-278.

[9] J. C. S. Souza, M. A. P. Rodrigues, M. T. Schilling, and M. B. D. C. Filho, Fault location in electrical power systems using intelligent systems techniques, *IEEE Trans. Power Del.*, Vol. 16, No. 1, Jan. 2001, pp. 59-67.

[10] C. Y. Teo and H. B. Gooi, Artificial intelligence in diagnosis and supply restoration for a distribution network, *IEE Proc. Gener. Transm.Distrib.*, Vol. 145, No. 4, Jul. 1998, pp. 444-450.

[11] J. A. Momoh, L. G. Dias, and D. N. Laird, An implementation of a hybrid intelligent tool for distribution system fault diagnosis, *IEEE Trans. Power Del.*, Vol. 12, No. 2, Apr. 1997, pp. 1035-1040.

[12] F. Mekic, K. Alloway, C. Angelo, and R. Goodin, Fault detection isolation and restoration on the feeder (FDIR): Pick your technology, *in Proc. 21st Int. Conf. Elect. Distrib.*, Frankfurt, Germany, Jun. 2011, pp.1-8.

[13] R. Wernsing et al., Implementation of an innovative advanced loop scheme to provide distribution reliability improvement, *in Proc. IEEE Rural Elect. Power Conf.*, Orlando, FL, USA, May 2010, pp. B2-B2-8.

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

[14] S. Rusitschka, K. Eger, and C. Gerdes, Smart grid data cloud: A model for utilizing cloud computing in the smart grid domain, *in Proc. 1st IEEE Int. Conf. Smart Grid Commun., Gaithersburg*, MD, USA, Oct. 2010, pp. 483-488.
[15] L. Whei-Min and C. Hong-Chan, A new approach for distribution feeder reconfiguration for loss reduction and service restoration, *IEEETrans. Power Del.*, Vol. 13, No. 3, Jul. 1998, pp.870-875.
[16] M. R. Kleinberg, K. Miu, and H.-D.Chiang, Improving service restoration of power distribution systems through load curtailment of in-service customers, *IEEE Trans. Power Syst.*,
Vol. 26, No. 3,Aug. 2011, pp.1110-1117.
[17] D. Shirmohammadi, Service restoration in distribution networks via network reconfiguration, *IEEE Trans. Power Del.*, Vol. 7, No. 2, Apr. 1992, pp. 952-958.

[18] M.-S. Tsai, Development of an object-oriented service restoration expert system with load variations, *IEEE Trans. Power Syst.*, Vol. 23, No. 1, Feb. 2008, pp. 219-225.
[19] S. Srivastava and K. L. Butler-Burry, Expert-system method for automatic reconfiguration for restoration of shipboard power systems, *IEE Proc. Gener., Transm. Distrib.*, Vol. 153, No. 3, May 2006, pp. 253-260.
[20] S. J. Lee, K. H. Kim, H. Y. Kim, J. K. Lee, and K. Y. Nam, Expert system-aided service restoration in distribution automation, *in Proc. IEEE Int. Conf. Syst. Man Cybern.*, Vol. 1. Chicago, IL, USA,Oct. 1992, pp. 157-161.