RESEARCH ARTICLE OPEN ACCESS

Modelling of Smart Auto-Recloser with Over Current Protection

Abdrabou Ashour
Public Authority for Applied Education & Training, Kuwait

ABSTRACT
In a Smart Grid, one of the important aspects of a smart distribution system is the integration of smart control and protection devices. An Auto-recloser is one of the important devices in the protection system protecting the OHL (Over Head Lines) which transmit power for long distances to the loads area from the distribution panels. It was necessary to find a new smart model for the Auto-recloser device to perform developments and test new techniques for improving the protection of the distribution systems in order to face and overcome the challenges of smart grids and distributed generation integration. This paper presents an improved model of a control circuit of auto recloser which is one of the most important equipment in smart grid. The modeled control circuit is synchronized with circuit breaker in such a way that after occurrence of fault, breaker recloses automatically without any human interference. Whenever transient fault occurs in the system at distribution level, auto recloser avoids outage for longer duration. However, if the fault is persistent then auto recloser isolates only affected part in the system and avoids outage in other parts of the system. A new feature of directional over current protection is added to the control circuit of the auto recloser to overcome the new challenge of reversed current that integration of DG imposes to the traditional radial distribution systems. A simulation of a real Over Head Line (OHL) in North Delta Electricity Distribution Company having an Auto-recloser device installed on it has been done and results were discussed.

***Keywords* -** Auto Recloser, Over Current Protection, Medium Voltage Distribution Network, Smart Grid

---

Date of Submission: 16-07-2018 Date of acceptance: 30-07-2018

I. INTRODUCTION

In electric power distribution networks, an Auto-recloser device is a circuit breaker equipped with a mechanism that can automatically close the breaker after it has been opened due to a fault. Auto-reclosers are used on overhead distribution lines to detect and interrupt transient faults. Since many short-circuits on overhead lines are transient, an Auto-recloser improves service continuity by automatically restoring power to the overhead line after a transient fault is eliminated. The Auto-recloser shall be designed for pole mounted or substation installation. All of the unit's protection, control and metering functions shall be electronically controlled within an integrated, modularized control unit. The pole mounted Auto-recloser device is used in the North Delta electricity Distribution Company (NDEDCo.) in the protection system of the rural Overhead lines.

North Delta Electricity Distribution Company (NDEDCo.) distribution network is supplied from the 220 kV Egyptian grid through 220/66/11 kV substations. The 11 kV substations sides supply 167 Distribution Panels (DP). The 11 kV network feeders consist of either rural lines (OHL) or urban underground cables [1]. Automatic reclosing is adopted in the 11Kv medium voltage distribution network of NDEDC in most of the overhead lines (OHL) that feeds rural areas in majority. Automatic reclosing is implemented in the NDEDC which is classified as a radial distribution network.

Various studies in NDEDCo. have shown that anywhere from 65%, to as high as 85%, of faults on most overhead lines are transient. A transient fault, such as an insulator flashover, is a fault which is cleared by the immediate tripping of one or more circuit breakers to isolate the fault, and which is eliminated when the line is re-energized.

Lightning is the most common cause of transient faults, partially resulting from insulator flashover from the high transient voltages induced by the lightning. Other possible causes are swinging wires and temporary contact with foreign objects. In NDEDCo. distribution network, there was recorded cases of electrical shocks of snakes and large birds landing on the conductors of the OHL causing a transient fault in the distribution system as the birds causes instantaneous contact of the OHL conductors then the bird falls of the conductors as soon as it gets shocked. Thus, transient faults can be cleared by momentarily de-energizing the line, in order to allow the fault to clear. Auto reclosing can then restore service to the line.

The remaining 15-35% of faults are semi-permanent or permanent in nature. A small branch falling onto the line can cause a semi-permanent fault. In NDEDCo. distribution network, most of the

OHL pass through agricultural lands and wooded areas which contains many trees that may swing with the air flow causing the conductors of the OHL to contact each other. In this case, however, an immediate de-energizing of the line and subsequent auto reclosing does not clear the fault. Instead, a coordinated time-delayed trip would allow the branch to be burned away without damage to the system.

Permanent faults are those that will not clear upon tripping and reclosing. An example of a permanent fault on an overhead line is a broken wire causing a phase to open, or a broken pole causing the phases to short together. Faults on underground cables should be considered permanent. Cable faults should be cleared without auto reclosing and the damaged cable should be repaired before service is restored. There may be exceptions to this, as in the case of circuits composed of both underground cables and overhead lines [9]. Refs. [10, 11] presented a model for direction over current and distance relays to protect the electric feeders. More ever they used the MATLAB/SIMULINK to simulate and test the presented models.

II. NDEDC DISTRIBUTION NETWORK PROTECTION

Protection devices in NDEDCo. distribution network vary from a feeder to another as feeders are classified in distribution panels to an incoming feeders and outgoing feeders. The incoming feeders adopted protection devices are over current, earth fault, directional over current and directional earth fault relays. Fig. 1 shows the typical Single Line Diagram (SLD) of the topology adopted in the NDEDCo. Distribution Panels (DP). The outgoing feeders adopted protection devices are over current and earth fault relays with Auto Recloser devices installed on certain outgoing feeders which feeds rural areas through OHL. These protection devices are attached to feeders in the DP which is considered the point of measurement, protection and control of the distribution network control center.

Integration of DG in such a network would cause many issues and challenges in the point of view of protection because of the change of the system parameters and power flow direction as the network becomes no more radial. Hence, it became a necessity to develop new adaptive protection techniques that has the ability to recognize the state of the grid and decide new settings to be uploaded to the protection devices which matches the new form of the grid either in case of DG connected on Islanded from the grid.

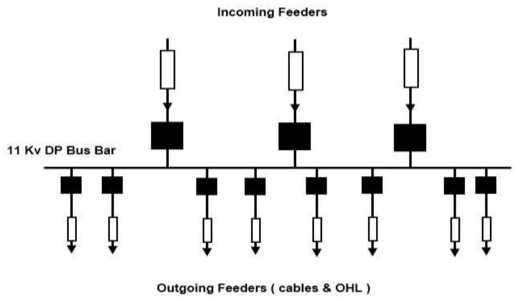

Fig. 1. SLD of the radial NDEDCo. distribution network

New technologies of protection of smart grids that contains both DGs and distribution grids in both cases of interconnected or disconnected are recently gaining interest. As a result, protection schemes are developed using current differential protection relays [2]. Adaptive over current protection with a certain proposed methodology taking in account the change in fault current setting with aid of developed communication technologies are discussed in [3]. In [4] various issues related to protection of micro grid are discussed, authors have used protection strategy, which adaptively selects different fault detection methods in grid connected mode and islanded mode, which improves the selectivity and reliability in protecting the micro grid. In [5] paper illustrates a novel protection scheme using digital over current relay (directional and non- directional) for microgrids and its performance verified by simulation in matlab/simulink.

III. MODELING OF DOC AUTOMATIC RECLOSER

Modeling has been performed in Matlab/Simulink with the help of SimPower-Systems toolbox (SPS) [6]. The loads of the outgoing feeders are centralized using constant impedances based on 11 kV. The system is verified with the actual onsite measurements of lines and cable impedances and lengths [1]. Then, the aging factor of the cables is calculated and implemented in the simulation.

Over current relay model is picked from [7] and some improvements and developments have been performed to the model to make it able to identify the direction of the current flowing in the system conductors depending on measurements of the phase shift between the current and the voltage waveforms. A novel Auto Reclosing system using Matlab/Simulink has also been developed to add the ability to the circuit breaker of reclosing after performing a trip due to a fault sensed by the Directional Over Current (DOC) relay mentioned before as shown in fig. 2, a view from the Matlab/Simulink of the proposed Auto

Recloser(AR) Device attatched in the power system and a screenshot from the developed over current relay mentioned in [7], also a screenshot for the novel proposed AR control circuit which is responsible for tripping and reclosing the circuit breaker to isolate or restore the power service in different fault cases.

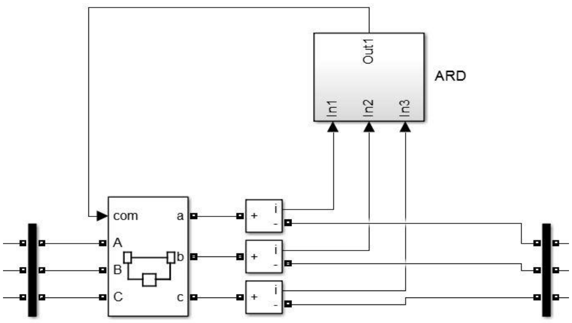

Fig. 2: The proposed AR Matlab/Simulink model

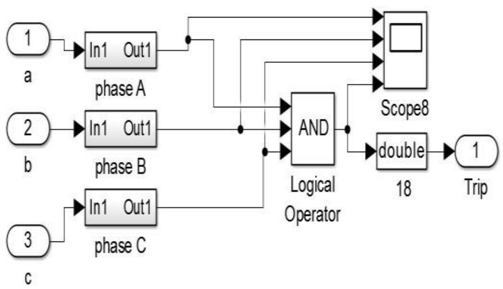

Fig. 2: The over current relay model from [7] with some improvements to fit the AR system

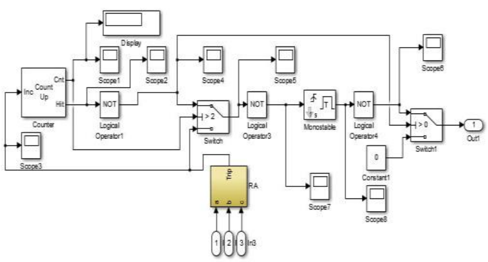

Fig. 2: The proposed AR Matlab/Simulink control circuit

The Auto Reclosing system model depends on tripping the circuit breaker for first time for 1 second when a fault is sensed by the DOC Relay and recloses the circuit breaker, then check if the fault is still in the system or not, if the fault is eliminated the circuit breaker closes and the system is restored successfully (case of transient fault), and if the fault is found again another trip signal goes to the circuit breaker for 1 second and then recloses again for the second time, then it checks if the fault is still in the system or not, if the fault is eliminated the circuit breaker closes and the system is restored successfully (case of semi-permanent fault), but if the fault is found again in the system, an instantaneous permanent lock out trip signal goes to the circuit breaker announcing a permanent fault occurrence in the OHL. Fig.3 shows a simplified flow chart for the operating theory of the AR system.

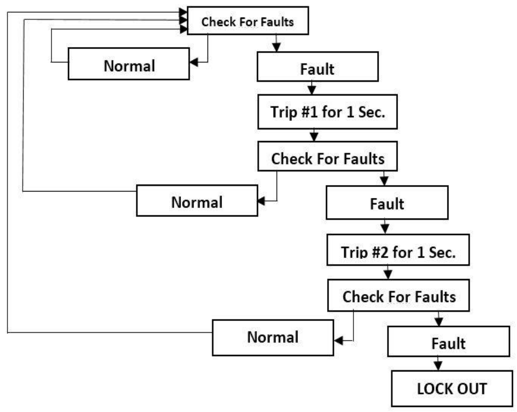

Fig. 3. The proposed AR model operation theory

As we mentioned before, the directional element in the proposed auto reclosing system plays a main rule in updating the network with new features to keep up with the coming soon Distributed Generation when works as a grid connected unit as it will be another source for fault currents in the point of view of the protection. Fig. 4 shows the challenge expected from integration of the DG with and without the Directional Auto Recloser. In fig. 4 the circuit breaker of the substation will trip due to the fault detection system of the substation protection, but the fault will not be isolated because of the DG contribution to the fault current. In fig. 5 the Directional Auto Recloser will sense the change in the current direction and will immediately send a permanent trip signal to the circuit breaker to isolate the faulted area.

The proposed DOC Auto Recloser would help to update the NDEDCo. distribution network protection system and protect the system utilities from the harmful fault currents even with DG integration.

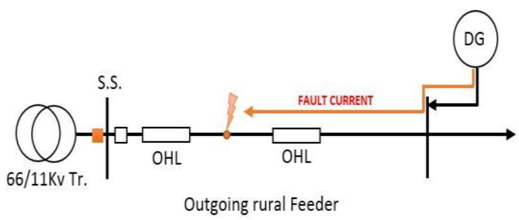

Fig. 4. Bi-directional current flow due to DG integration

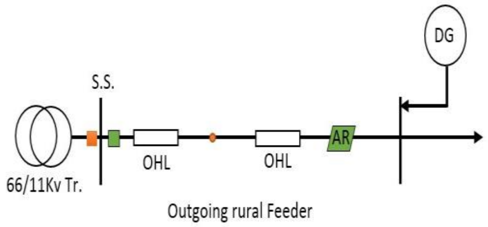

Fig. 5. Fault isolation by DOC auto recloser and C.B.

IV. MODELING OF THE PROPOSED AR IN A DISTRIBUTION SYSTEM

The proposed distribution system is a system with real data of conductors' length, resistance and real setting of the protection relays with their practical values. A real OHL called "Al-Roby'ah" with an Auto Recloser device installed is selected to perform the simulation. This OHL feeds heavy load industrial areas and is famous of being very long which makes it sensitive and more likely to be exposed to transient faults. Table 1 shows the OHL parameters and the protection over current relay and auto recloser device settings which are the parameters and settings used in the simulation. Fig. 6 shows a single line diagram of Al Robye'ah OHL with the protection devices time delay discrimination used in the system.

Table 1 System parameters and settings

Feeder	Impedance (ohm/km)		O.C. relay setting (A)	Auto Rec. Setting (A)
	R	X_L		
Al Roby'ah	8.588	8.98	600 A	500 A

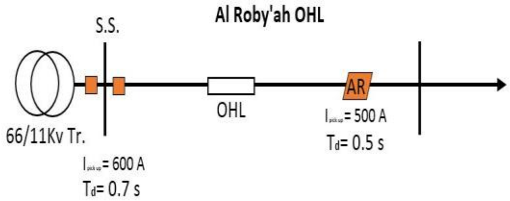

Fig. 6. Simulated OHL protection system

The simulated protection scheme depends on the Definite Time characteristics adopted in the NDEDCo. to differ from the in zone or out of zone faults, which guarantee a high level of continuity of feeding the electrical network with power and avoid tripping safe areas for no need**.**

V. AUTO-RECLOSER SIMULATION AND RESULTS

A. Permanent Fault Case

The permanent fault case is that case in which the Auto Recloser device is supposed to isolate the faulted area of the system to protect the network from harmful consequences. The over current protection built-in the AR device will pick up because of the high current level caused by the permanent fault occurrence and consequently the trip signal will take the time delay setting then the circuit breaker opens its contacts in its first trial to eliminate the fault. The same steps would happen in the second trial, but in the third trial an instantaneous trip signal without time delay goes to the circuit breaker as the system is now sure enough that the fault is permanent and needs the AR to lock out till the maintenance teams fix the problem in the OHL. Fig.7 shows the proposed AR system performance in the case of a permanent three phase to ground fault. Fig. 8 shows the proposed AR system performance in the case of a permanent double phase to ground fault which is also common in the NDEDCo. in the form of OHL conductors swinging due to the air flow. As we notice in Fig.8 the fault current level is not high as the three phase fault so the last lock out signal performed a time delay and wasn't instantaneous as the three phase fault .

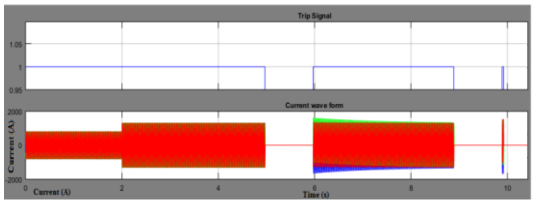

Fig. 7. AR performance in case of 3-phase permanent fault

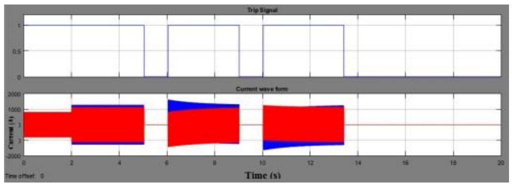

Fig. 8. AR performance in case of 2-phase permanent fault

B. Semi-Permanent Fault Case

The Semi-Permanent fault case is the case in which the object that caused fault will need extra time to be burnt and falls down from the OHL revealing the contact between the conductors which means that there will be no more faults in the system and the AR will reclose its contacts successfully and restore the system safely without faults and without extra outage time which affects the reliability of the distribution system and the quality of continuous power feeding to the customers. Fig. 9 shows the proposed AR system performance in the case of semi-permanent three phase fault in which we notice that the AR performed two trips and didn't trip for the third time as the fault cause was burnt letting the conductors safe. Fig.10 shows the proposed AR system performance in the case of a semi-permanent double phase fault.

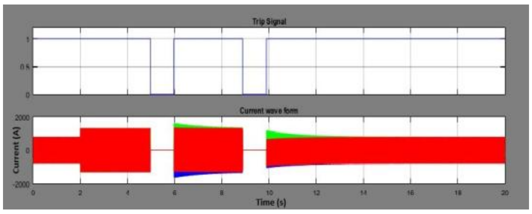

Fig. 9. AR performance in case of 3-phase semi-permanent fault

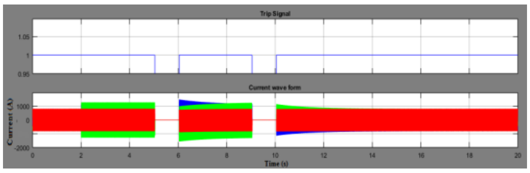

Fig. 10. AR performance in case of 2-phase semi-permanent fault

C. Transient Fault Case

The Transient fault case is the case in which the AR is supposed to trip its contacts and reclose it restoring the system as the transient fault is a short duration fault may cause the system protection to trip causing a long-time outage but the existence of the AR device reveals that big problem that may face most of the OHL in the NDEDCo. distribution network. Fig. 11 shows the proposed AR performance in the case of a transient fault which successes to eliminate the transient fault safely and reclose its contacts again to restore the service to the customers. Fig. 12 also shows the proposed AR device performance in the case of a double phase fault which is common in the distribution system in the form of conductors swinging due to fast wind or storms.

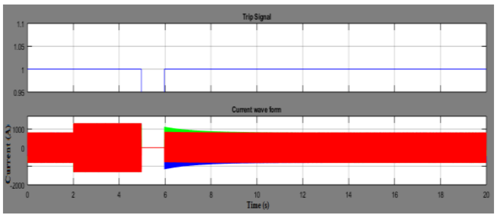

Fig. 11. AR performance in case of 3-phase transient fault

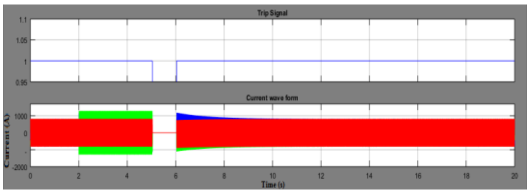

Fig. 12. AR performance in case of 2-phase transient fault

VI. CONCLUSION

This paper proposed a novel Auto-recloser device with Directional Over Current protection built-in it to add a new feature to the protection system of the NDEDCo. as a preparation for DG integration which presents new challenges for the traditional protection system. A simulation has been performed for the system to verify the performance of the Automatic Reclosing which successfully fulfilled the purpose of the Auto-Recloser device and eliminated the transient and semi-permanent faults from the distribution overhead lines. Two types of faults which are commonly found in the distribution system are simulated and the simulation results were studied.

REFERENCES

[1]. M. King, B. Zhu, and S. Tang, "Optimal path planning," Mobile Robots, vol. 8, no. 2, pp. 520-531, March 2001.

[2]. H. Simpson, Dumb Robots, 3rd ed., Springfield: UOS Press, 2004, pp.6-9.

[3]. M. King and B. Zhu, "Gaming strategies," in Path Planning to the West, vol. II, S. Tang and M. King, Eds. Xian: Jiaoda Press, 1998, pp. 158-176.

[4]. B. Simpson, et al, "Title of paper goes here if known," unpublished.

[5]. J.-G. Lu, "Title of paper with only the first word capitalized," J. Name Stand. Abbrev., in press.

[6]. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Translated J. Magn. Japan, vol. 2, pp. 740-741, August 1987 [Digest 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[7]. M. Young, The Technical Writer's Handbook, Mill Valley, CA: University Science, 1989.

[8]. Naveenkumar R Kulkarni "A review on Autorecloser control methodology for improved distribution reliability", April 2014.

[9]. Elisabete Faria Almeida "Real-time Closed-Loop Test to Adaptive Protection in a Smart-Grid Context", July 2014.

[10]. A. Y. Hatata, M. Dewedar, I. I. Mansi, "Modeling and Simulation of Mho Relay using Matlab/ Simulink, "MEPCON'15, conference, December 15-17, 2015, Egypt.

[11]. A. I. Ibrahim, A. Y. Hatata, A. Hassan and M. S. Kandel," Modelling and Simulation of a Smart Auto-Recloser With a Directional Over Current Protection," MEPCON'15, conference, December 15-17, 2015, Egypt.

Abdrabou Ashour "Modelling of Smart Auto-Recloser With Over Current Protection "International Journal of Engineering Research and Applications (IJERA) , vol. 8, no.7, 2018, pp.01-05