Modeling Of Auto Recloser for Smart Grid

Mandar P. Katti, Jangamshetti S. H, Ajay Rege

Abstract: *Power Distribution Networks have been operated in an easy and simple unidirectional way. Therefore, no automatism even remote control technology was applied to Ring Main Units or Sectionalizer close to the load in the distribution network. However, increase in load demand has led to instability in system which ultimately resulted into outages in power system. This paper presents the SIMULINK modeling of a control circuit of autorecloser 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. The other important aspect of smart grid is to make power system self sufficient. The importance of having Decentralized Generation at Medium voltage and Low voltage level is explained. Whenever transient fault occurs in the system at distribution level, autorecloser avoids outage for longer duration. However, if the fault is persistent then autorecloser isolates only affected part in system and avoids outage in other parts of system.*

Keywords: *DG, MV, LV, HV, Distributed Energy Resources, Present and Future power system.*

I. Introduction

Switchgear and control gear are necessary at every switching point in power systems. The switchgear and control gear industry in India is a fully developed industry, producing and supplying a wide variety of switchgear and control gear items needed by industrial and power sectors.

Autorecloser is a circuit breaker equipped with a mechanism that can automatically close the breaker after it has been opened due to a fault [2]. Automatic circuit reclosing is extensively applied to overhead line circuits where a high percentage of faults that occur are transient in nature. The Smart Grid is idea of a better electricity delivery infrastructure. Smart Grid implementations will certainly increase the quantity, quality, and use of information available from advanced sensing, computing, and communications hardware and software [1]. The Smart Grid is idea of a better electricity delivery infrastructure. Smart Grid implementations will certainly increase the quantity, quality, and use of information available from advanced sensing, computing, and communications hardware and software [1].

II. Smart grid and Autorecloser

a. Smart grid

The vision of a smarter grid is to make the electric power system more interactive, interoperable, reliable, and robust—"self-healing".

India's electric grid should make three fundamental improvements to the existing grid:

1] Advanced metering to reduce AT&C losses that are at an unacceptably high-level presently

2] Automation to measure and control the flow of power to/from consumers on a near real-time basis and improve the system reliability

3] Moving to a smart grid to intelligently manage loads, congestion and shortfall From the last point it is clear that to have decentralized generation it will help to manage loads and help to overcome shortages in power.

Due to increasing power demand in far-flanged areas it is very difficult to satisfy these demand as it is uneconomical to supply power to these areas. Hence, Decentralized Energy Resources (DER) is used in such areas.

The overall problem when integrating DG in existing networks is that distribution systems is a unidirectional system from the central generation downstream to the consumer. The conventional protection systems were designed in common Medium Voltage (MV) and Low Voltage level (LV) distribution networks [3].

b. Autorecloser

Automatic reclosing is widely adopted in medium voltage networks. Automatic reclosing is easy to implement in a radial distribution network. It becomes problematic when distributed generation is introduced to the network [4]. The ARD model integrated to the circuit breaker developed in MATLAB SIMPOWERSYSTEMS is adapted from the study conducted by MM EL-Saadawi in reference [6] with certain modifications in fast curve block.

Autorecloser functions on the principle of Coordination of Inverse Time Overcurrent Relays with Fuses. The duty of protection equipment is to allow overload currents that occur during operation, yet to prevent impermissible loading of lines and equipment [10]. To avoid damages in the case of short-circuits the relevant equipment must be tripped in the shortest possible time [3]. On the other hand only few feeders or loads as possible should be disconnected from supply. The protection relays available in the power system must recognize the fault, perform tripping themselves or give trip commands for the relevant switching device.

III. Autorecloser in present system and future power system

Figure 4.1 shows the control circuit of autorecloser which is located inside the subsystem.

- **Sine wave**: The sine wave block is the representation of AC source that is considered as supply source. For recloser AC (230V) or DC (110V) source can be considered as supply source.
- **RMS (Root Mean Square)**: The RMS block is used to measure the root mean square value of the instantaneous current passing through the recloser.
- **Gain**: The gain block is used to obtain peak value of the instantaneous current passing through the recloser.
- **Time-Current Characteristics**: The peak value will pass to two blocks; the first is a Function Block

parameter which contains the fast curve of the recloser (TCC). This fast curve is based upon the IEEE STANDARD INVERSE-TIME characteristic equations. The equation for Time Current Characteristics [3] is given as,

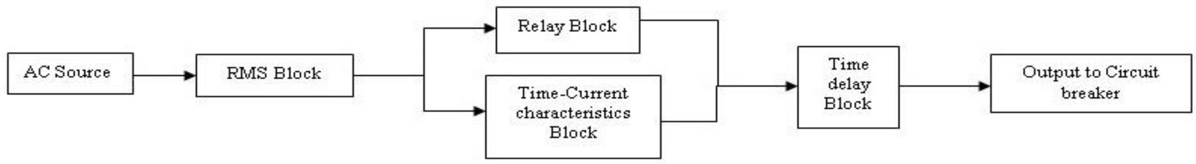

Figure 4.1: Recloser control circuit

$$tt = \frac{\frac{K_d}{\tau_s}}{((\frac{I}{I_p})^p - 1)} TDS \qquad (1)$$

Where,

tt: Trip time,

K_d: drag magnet damping factor,

τ_s: Initial spring torque,

I: normal current,

P: constant exponent,

TDS: Time dial setting,

I_p: relay pickup

The equation (1) can be further modified as,

$$tt = \frac{A}{M^p - 1} TDS \qquad (2)$$

Where,

$A = {K_d}/{\tau_s}$,

$M = {I}/{I_p}$,

The output of this block is a time corresponding to the passing current.

- **Relay**: The next block is a Relay Block which allows its output to switch between two specified values (0, 1). If the current is less than a specific value (reclosers setting) the relay output will stay at zero value, if the current value is greater than that specific value and more the output of the relay will be stick with 1.
- **Variable time delay**: Variable Time Delay block receives the output of the previous two blocks as an input. The output of that block will be either 0 or 1 after a delayed time. If a fault current is passed through the relay; its output signal is 0, and this signal will be delayed (by the variable time delay block) for a short time inversely proportional to the fault current value. The output of the last block is a signal that opens the breaker switch. If the fault is a temporary one, the relay output will be 1, so that the breaker switch closes.
- **Scope**: The signal in the recloser control circuit is monitored at various levels with the help of scope. Basically, there are 4 scopes used at different level in recloser control circuit.

Computational block diagram of present power system

The power system model shown in figure 4.2 is of generation, transmission, distribution system. The focus is basically on distribution system as autorecloser is used in

The high percentage of temporary faults allows the application of a device with a dual timing characteristic to coordinate with fuses, Sectionalizer, and other automatic circuit reclosers placed on the system.

The number of reclosing events, the reclosing interval delays, fast and time delay (also referred to as slow curve selection, and minimum trip selection must be chosen to satisfy a number of objectives.

The block diagram of present power system given in figure 4.2 indicates the presence of autorecloser in the system.

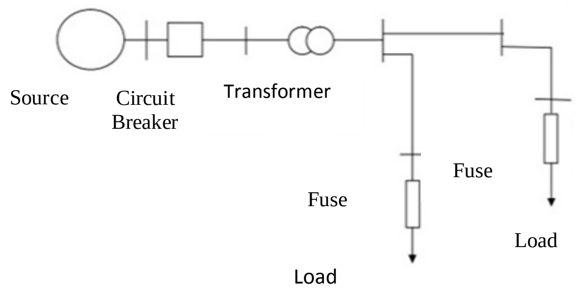

Figure 4.2: Present power system

Computational block diagram of future power system using autorecloser and decentralized generation

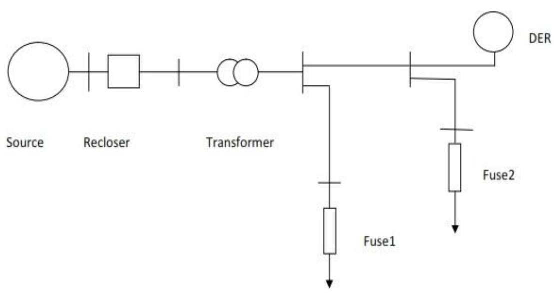

Figure 4.3: Decentralized generation connected to the system.

Figure 4.3 illustrates a Decentralized generation connected to the system. Decentralized generation is defined as it can be defined as the development of small, modular electric

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generation close to the point of consumption [11]. DER's impact on the power system industry and these impacts can be categorized as, financial, technical, and regulatory impacts. Integration of DG in distribution networks may impact the network protection system [4].

IV. Results and Discussion

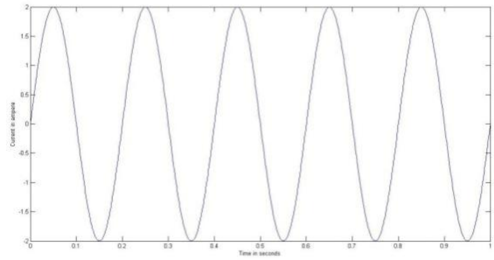

Figure 5.1: Input to recloser control circuit

Figure 5.1 shows the sinusoidal AC instantaneous input fed to the autorecloser. Generally, the autorecloser is fed AC as input or DC in case of power failure. The sinusoidal input is resemblance of AC input fed to the recloser control circuit.

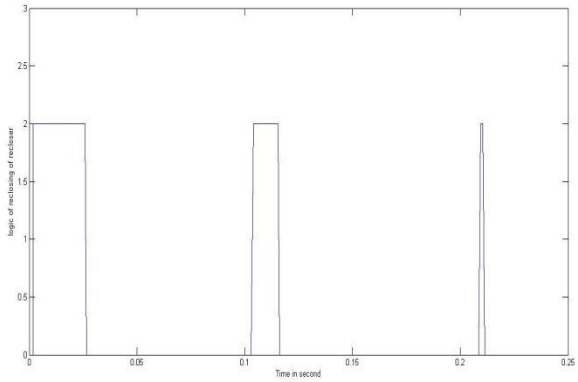

Figure 5.2: Reclosing attempts carried out by recloser

Figure 5.2 shows the reclosing attempt carried out by autorecloser when fault is still persistent even after first reclosing attempt. The frequency of reclosing depends upon system design, its capacity to withstand the continuous making and breaking of the breaker. Ideally, for distribution system the reclosing process is limited to 3 to 4 attempts to avoid major damage to the circuits.

When a temporary fault occurs in the system, the breaker contacts get separated and reclosing is initiated. As the fault is temporary, the recloser generally resumes supply in first attempt itself. However, sometimes it may take 2 or 3 attempts.

When persistent fault occurs in the system, as breakers keeps on tripping due to presence of fault and which results into failure in reclosing of breaker. Hence, system goes into lockout mode.

Various fault conditions in the present power system

The power system block diagram is constructed in SIMULINK environment and is simulated under various fault conditions

Figures 5.3 and 5.4 clearly states that when phase to phase fault occurs in the system as no recloser is present in the system, the power system is needed to be checked for any existence of fault. This leads to increase in the outage time. In present power system, engineers has to go and manually check whether the fault is existing or not and after confirmation can resume the supply. But, the other parts of the system which are not affected by fault, faces outage.

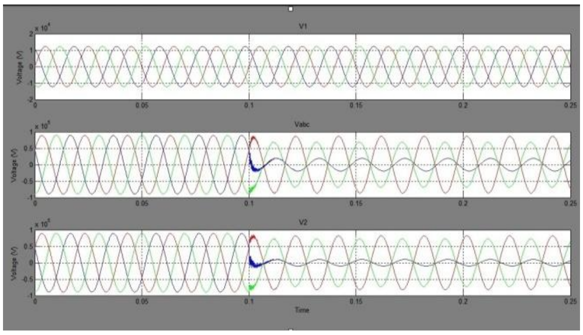

Figure 5.3: Voltage output near generation for during phase to phase fault.

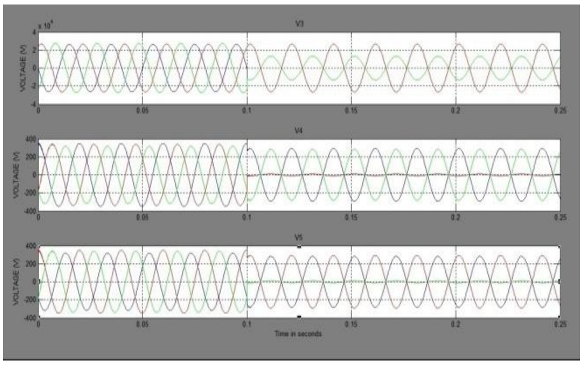

Figure 5.4: Voltage output near load during phase to phase fault

Various fault conditions in the future power system

Future power system basically consists of autorecloser and DG systems as parts of distribution system.

Figure 5.5 and 5.6 shows the effect of having autorecloser in distribution system during phase to phase fault in the system. Due to the presence of autorecloser in the distribution system after two attempt the recloser resumes the supply to the affected system. This is possible only if the fault is temporary in nature.

When DG system is present in the system at MV and LV level the reactive power flowing the system is affected. It also affects the autorecloser by causing recloser-fuse mis-co-ordination.

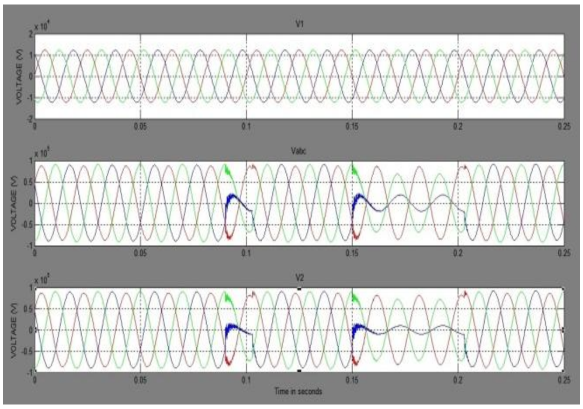

Figure 5.5: Voltage output near generation during phase to phase fault in presence of autorecloser.

Figure 5.7 and 5.8 clearly explains the necessity of converters in DG system. When converters are used it can observed that reactive power is under control which justifies the presence of converters in DG to obtain balanced output.
The outputs shown in figure 5.7 and 5.8 are obtained in absence of autorecloser.

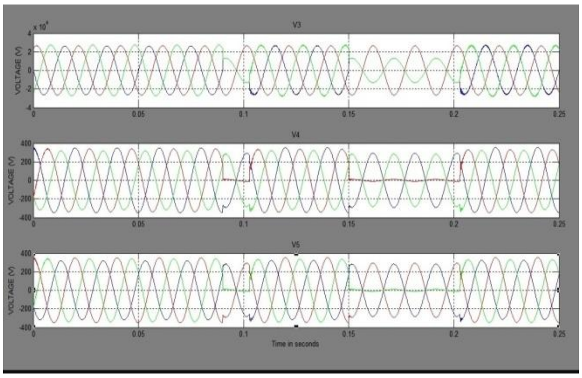

Figure 5.6: Voltage output near load during phase to phase fault in presence of autorecloser

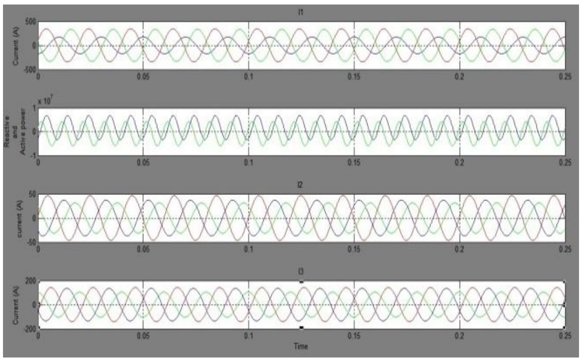

Figure 5.7: Current and reactive power output in presence of DG (15kV) system at distribution level

Figure 5.9 and 5.10 explains that in presence of autorecloser and properly designed the DG the system can overcome any type of temporary faults.

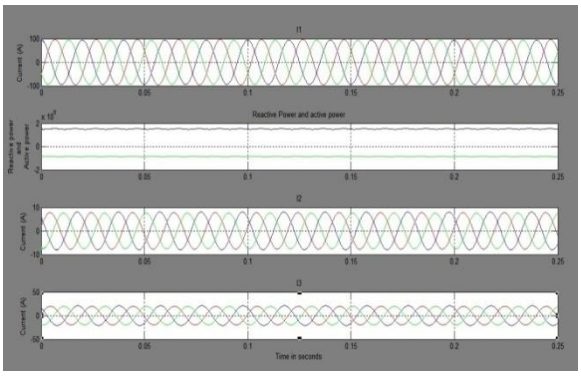

Figure 5.8: Current and reactive power output in presence of DG (415V) system at distribution level.

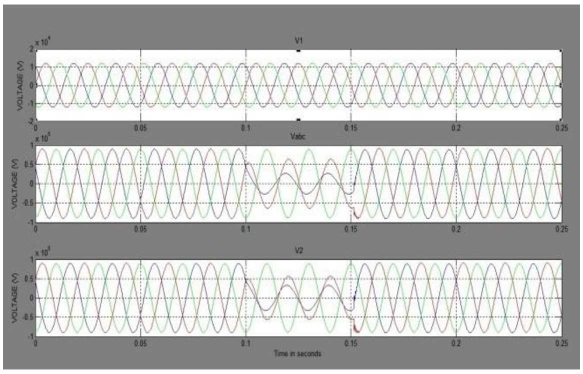

Figure 5.9: Voltage output near generation during phase to phase fault in presence of DG and recloser.

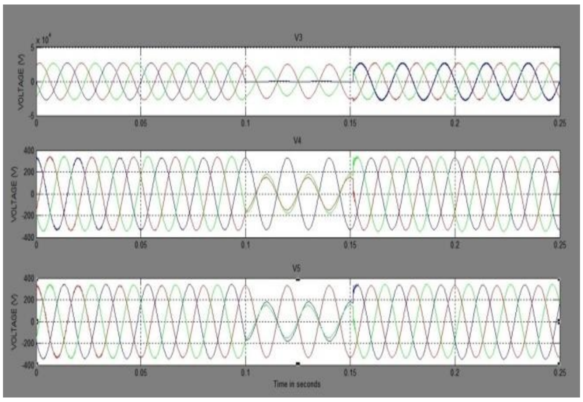

Figure 5.10: Voltage output near load during phase to phase fault in presence of DG and recloser.

Comparison of the results

Table 5.11: Theoretical and simulation values of reclosing time for given values of current.

Current (A)	**Theoretical data (Reclosing time in Seconds)**	**Simulation data (Reclosing time in Seconds)**
290	0.5	0.4
320	0.3	0.3
400	0.2	0.2
490	0.15	0.1
550	0.1	0.09
650	0.09	0.07
810	0.05	0.04
1150	0.04	0.03
2000	0.033	0.02
3000	0.025	0.01
4000	0.015	0.009

Table 5.11 illustrates the theoretical and simulated data for given values of the current flowing through the recloser.
Figure 5.12 and 5.13 clearly shows the difference in the reclosing time obtained between theoretical data and simulated data.

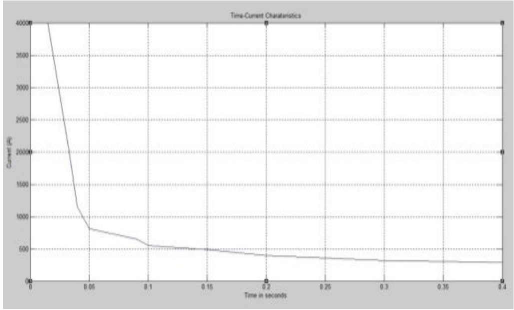

Figure 5.12: Time Current charateristics for theoritical data

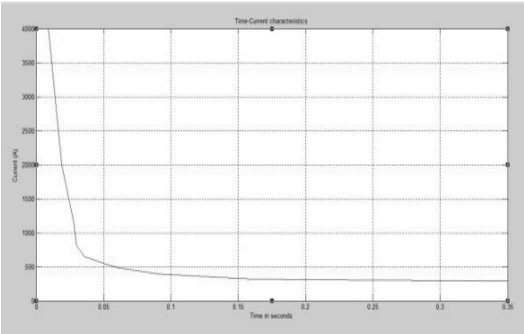

Figure 5.13: Time current characteristics for simulated data.

V. Conclusion

A detailed study is done concerning the application of the autorecloser in the present and future power system which was presented using SIMULINK toolbox. This aimed on improving the voltage, current and reactive power flow in power system. The recloser results obtained are compared to determine the better design of the control circuit. Also, the correct position of the Decentralized Generation (DG) in the distribution system helps in improving system performance during fault.

The results obtained clearly states that the use of autorecloser with some modification will be beneficial if implemented in Indian power system. The use of decentralized generation in the distribution system will help the power system in reducing the outage time by diverting load to unaffected part. However, the decentralized generation system affects the recloser and fuse co-ordination. This problem is solved by selecting a DG system which does not affect recloser fuse co-ordination.

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