OPTIMAL RECLOSING TIME TO IMPROVE TRANSIENT STABILITY IN DISTRIBUTION SYSTEM

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ABSTRACT

The power industries have paying their attention on distributed generations (DGs) due to the improvement in new technology like fuel cell, wind turbine, photo voltaic (PV). Hence distributed generations have attained a lot of consideration in the power industry due to market deregulations and ecological concerns. The paper presented optimal reclosing of circuit breakers for DG connected IEEE nine Bus system. The optimal reclosing technique (ORT) is derived from the total load angles of the DGs. First the optimal reclosing times are determined, and then the performance of the proposed reclosing method is compared with the conventional reclosing technique. Both transient and permanent faults at different points in the power system model are considered. Two indices are considered to evaluate the system performance. The significance of this technique is that it can be implemented for online application because it not need for relevant large amount of calculation. The proposed method is verified by simulation study using MATLAB/SIMULINK. Simulation studies demonstrate that the proposed technique is able to determine the optimal reclosure time and enhancing system stability. Moreover, the performance of the proposed method is better than that of the conventional reclosing method.

INTRODUCTION

Environmental and economical issues have driven significant increases in the development of DG. The implementation of these generations may influence the technical aspects of distribution systems. The operation of DG can cause unwanted operation of protection and the fault level may be changed [1]. As the penetration level of DG becomes higher, the impact of DG on transient stability cannot be neglected.

Operation of transmission and distribution networks faces a lot of difficulties regarding the trip and close decision on each line and their consequences on the stability of the network. A successful automatic close back in decision to a line can increase the reliability of the network [2]. The autoreclosing can recover distribution lines, transmission lines and circuit breakers which are damaged by electrical faults. The successful autoreclosing can enhance a transient stability and the reliability of power systems. However, the unsuccessful autoreclosing may cause the system unstable and the damage of system and equipment. The presence of distributed generation can cause the unsuccessful autoreclosing because the DG may sustain feeding fault current during the autoreclose open time prohibiting the intended arc extinction [1]. Therefore, references [3] suggest that the DG must be disconnected clearly before the reclosing. But, the frequent disconnection of DG may cause the decrease of power quality, such as outage and voltage sag. In addition, the reconnection after disconnection of DG may cause the secondary transients to distribution systems.

Clearance instance of the fault is usually followed by electrical power swings. These swings are likely to be hazardous as they potentially mislead distance protection and have thermal effects on generators [4]. When a large amount of electrical power is oscillating, aforementioned effects could result in cascading outages of lines, out of step condition for network machines and eventually transient instability. Therefore, prevention from dangerous power swings is essential. The optimal reclosure time is of great importance to reduce the system oscillations and enhance the transient stability. A traditional reclosing scheme depicts the reclosing of circuit breakers after a prescribed time period when the arc extinction using a simple equation based on statistical data [5]:

$$T_{arc} = (10.5 + KV/34.5) \ \text{cycles} \qquad (1)$$

where, kV is the line voltage. This equation takes only the line voltage into account. Therefore, the value calculated by equation (1) is not exact, then the circuit breaker would not be able to reclose successfully, this is an indication of the unstable state of the system. Since transient stability is dependent on the generators state, to enhance the transient stability we have to discover an optimal reclosing time when reclosing of the circuit breakers will enhance the transient stability of the system effectively.

The paper presented optimal reclosing time (ORT) based on the total load angles of the DGs. First the optimal reclosing times are determined, and then the performance of the proposed reclosing scheme is compared with the conventional reclosing scheme. Both transient and permanent faults at different points in the power system model are considered to prove the ability of the proposed scheme. By employing the suggested algorithm, we can maintain transient stability.

BASIC PRINCIPLE OF ADAPTIVE OPTIMAL RECLOSURE

Conventional auto-reclosing can affect the stability of the system, as it is dependent on the generator state of reclosing instances. So, to improve the transient stability of the system, circuit breakers should be closed at an optimal reclosing time at the system disturbance has no effect after reclosing operation. The optimal reclosing time is considered as the point which should be satisfied the following condition. The point when the system disturbance at the minimum without reclosing operation [6].

Recently proposed techniques seem effective in discriminating permanent from transient faults [7] and [8], thus preventing autoreclosers from reclosing onto permanent faults. Also in some cases reclosing onto permanent faults cannot be prevented. However, the permanent fault may not necessarily lead the system to lose stability, provided that an optimal choice of reclosing time is performed. As far as transient faults are concerned, reclosing time will mainly affect system oscillations, but can hardly worsen system stability if the un-reclosed system is already stable. However, damping improvement is a requirement that can be satisfied by a reclosure at an optimal time. Hence, for both permanent and transient faults, the optimal reclosure can be an effective way to improve dynamic behavior of power systems.

DESCRIPTION OF MODEL SYSTEM

For the analysis of optimal reclosing techniques, the IEEE nine bus power system with multiple DGs have been presented [9]. The single line diagram of the IEEE 9-bus test system is shown in Figure 1. The line complex powers are around hundreds of MVA each. In this study the IEEE 9-bus system is configured with DGs such solar PV plant (G1) and wind farm (G2) with the capacity of 247.5 MVA and 192 MVA respectively. The synchronous DG was modeled as 4th order synchronous generator with AVR [10]. The values of loads (A, B and C) are 125 MW, 90 MW and 100 MW respectively [9]. F1, F2 and F3 are considered as the fault positions.

LOAD ANGLE BASED OPTIMAL RECLOSING TECHNIQUE

Conventional auto-reclosing of circuit breakers can affect the stability and power quality of the system, as it is dependent on the behavior generator state of reclosing instances. So, to improve the transient stability, the circuit breakers should be closed at an optimal reclosing time at the system disturbance has no effect after reclosing operation.

Real time measurement is required to capture the optimal reclosure time. When a fault occurs, the optimal reclosure unit starts to function after the circuit breakers have tripped. The proposed method is shown in figure 2. The steps of the ORT process are: The required signal needed to be captured is the load angles of the generators G1 and G2, and then calculation of the total load angles can be done through the global positioning system (GPS). In this method, the optimal reclosing time is considered as the point when the total load angles oscillation of the generators without reclosing operation becomes the minimum. Figure 2 shows the functional block diagram of the mentioned optimal reclosing scheme including GPS. Using the computer, the central control office can then detect the optimal reclosing time readily.

The behavior of the proposed method is estimated by using the voltage and speed indices. The lower indices values imply that the higher the system's performance is.

$$V_{index} = \int_0^T |\Delta V| dt \qquad (2)$$

$$W_{index} = \int_0^T |\Delta W| dt \qquad (3)$$

where, ΔW and ΔV are the deviation of the speed and voltage of the generators from their steady-state values. The ΔW and ΔV are expressed as:

$$\Delta W = W - W_0 \qquad (4)$$

$$\Delta V = V - V_0 \qquad (5)$$

where, W and V are instantaneous values of speed and voltage respectively, and the W_0 and V_0 are steady state values of speed and voltage, respectively.

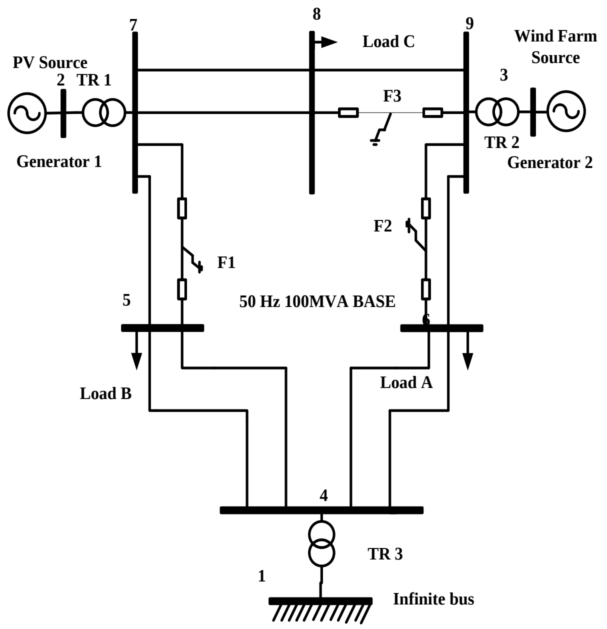


Figure 1: DG connected IEEE nine bus system model.

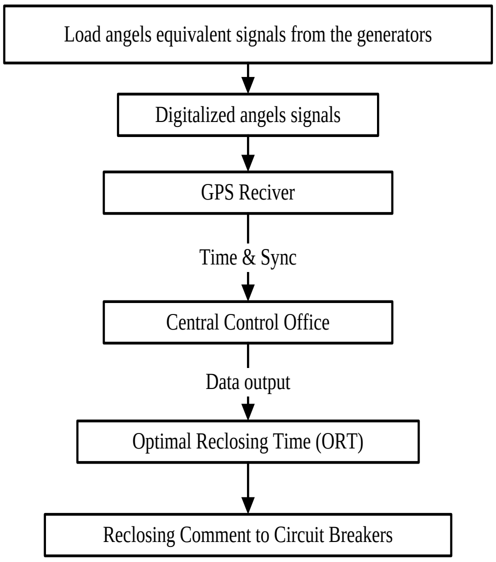


Figure 2: Flow chart of proposed ORT scheme

SIMULATION RESULTS AND DISCUSSIONS

Using the proposed scheme, the values of the first optimal reclosing time of different fault positions for transient and permanent faults are calculated from the sum of the load angles and represented in the Table 1. Figure 3 shows the sum of the load angles for the 3LG (three phase-to-ground) transient fault at F_1 without reclosing operation to find out the optimal reclosing time. The fault locations F_1, F_2 and F_3 are used in the system model. The proposed method and the conventional method are studied respectively. The conventional method employed herein is a fixed dead time interval [11].

Table 1: ORT values for permanent and transient faults for multi-machine system

Fault Nature	Fault Type	Fault position	Proposed method (sec)	Conventional method (sec)
Transient Fault	LLLG	F_1	1.621	1.9
		F_2	1.532	1.9
		F_3	1.603	1.9
	LG	F_1	1.525	1.9
		F_2	1.539	1.9
		F_3	1.608	1.9
Permanent Fault	LLLG	F_1	1.699	1.9
		F_2	1.705	1.9
		F_3	1.703	1.9
	LG	F_1	1.612	1.9
		F_2	1.586	1.9
		F_3	1.539	1.9

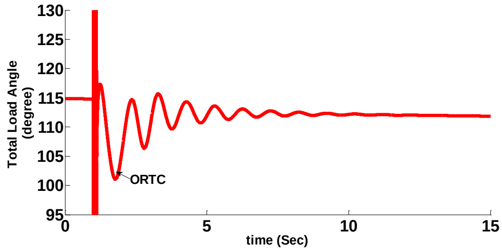
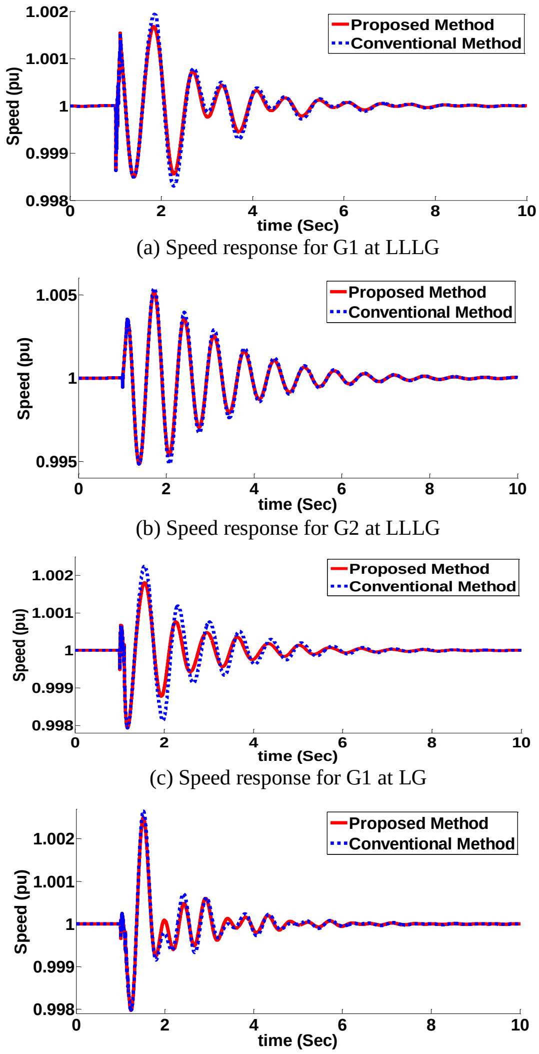


Figure 3: Total load angles response for determining ORT.

Figure 4 shows the speed response for generators G_1 and G_2 when LLLG transient faults occurred at point F_2 with breaker reclosing according to the proposed method and conventional method. In this Figure, power swing mitigation is noticeable on reclosing based on total load angle method.



(a) Speed response for G1 at LLLG

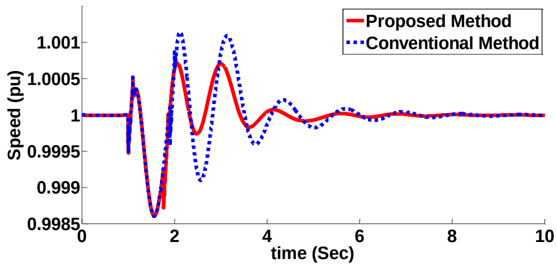
(b) Speed response for G2 at LLLG

(c) Speed response for G1 at LG

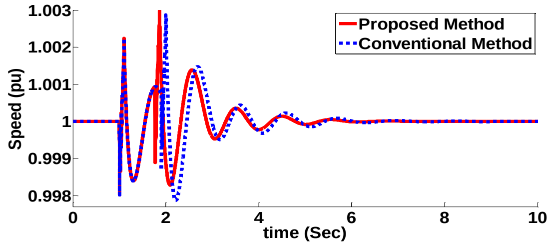
(d) Speed response for G2 at LG

Figure 4: Response of the speed for LLLG and LG transient fault at point F_2 with breaker reclosing according to conventional method and proposed method

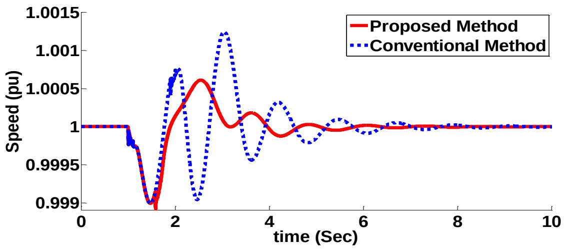
Figure 5 shows the speed response for generators G_1 and G_2 when LLLG permanent faults occurred at point F_3 with breaker reclosing according to the proposed method and conventional method.



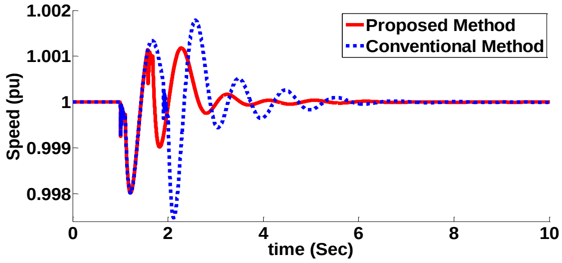
(a) Speed response for G1 at LLLG



(b) Speed response for G2 at LLLG



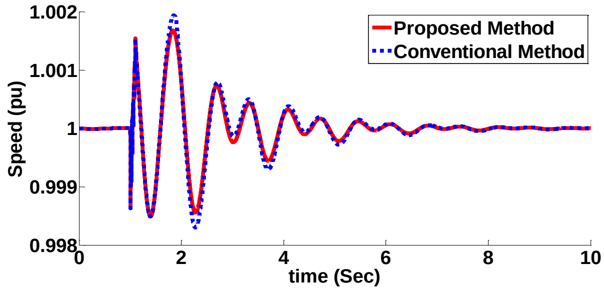
(c) Speed response for G1 at LG



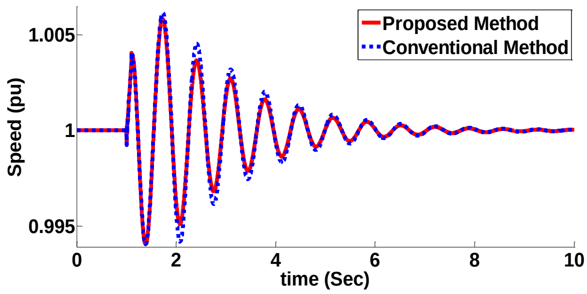
(d) Speed response for G2 at LG

Figure 5: Response of the speed for LLLG and LG permanent fault at point F_3 with breaker reclosing according to conventional method and proposed method

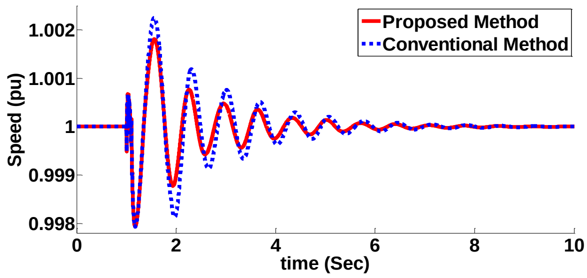
Figure 6 shows the speed response for generators G_1 and G_2 when LLLG transient faults occurred at point F_3 with breaker reclosing according to the proposed method and conventional method. It is concluded that when applying the proposed method to determine the ORT, system oscillations can be significantly mitigated by reclosing at the ORT based on the total load angle method.



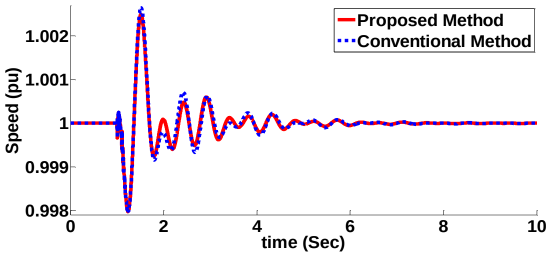
(a) Speed response for G1 at LLLG



(b) Speed response for G2 at LLLG



(c) Speed response for G1 at LG



(d) Speed response for G2 at LG

Figure 6: Response of the speed for LLLG and LG transient fault at point F_3 with breaker reclosing according to conventional method and proposed method

The speed and voltage indices for proposed method and conventional method in case of permanent and transient LLLG and LG faults are presented in Table 2. The values of speed and voltage indices using the proposed method are smaller than that in the conventional method. It is clearly seen from Table 2 that the proposed method has a good performance in comparison with the conventional reclosing method.

Table 2: W_{index} and V_{index} values for LLLG and LG transient and permanent faults

Fault Nature	Type of fault	Location fault	Conventional method (pu.sec)		Proposed method (pu.sec)	
			V_{index}	W_{index}	V_{index}	W_{index}
Tra. Fault	LLLG	F_1	0.231	0.0088	0.212	0.0080
		F_2	0.229	0.0118	0.224	0.0095
		F_3	0.199	0.0099	0.182	0.0086
	LG	F_1	0.218	0.0067	0.193	0.0062
		F_2	0.208	0.0074	0.166	0.0065
		F_3	0.168	0.0068	0.152	0.0061
Per. Fault	LLLG	F_1	0.181	0.0029	0.167	0.0022
		F_2	0.173	0.0029	0.165	0.0020
		F_3	0.269	0.0029	0.223	0.0022
	LG	F_1	0.182	0.0028	0.146	0.0018
		F_2	0.144	0.0029	0.135	0.0019
		F_3	0.192	0.0035	0.187	0.0021

CONCLUSION

A method for determine optimal reclosing time has been presented. The method depends on the synchronous generators load angles and predicts ORT for enhancement power system stability. The proposed scheme is verified by simulation study using MATLAB/SIMULINK. Simulation studies demonstrate that the proposed scheme is able to determine the optimal reclosure time and enhancing system stability. The lower voltage and speed indices values for the proposed method compared to the conventional method indicate better system's performance.

The advantages of the proposed method are summarized as follow:

- Enhancement transient stability.
- The execution of the proposed reclosing scheme is better than that of the conventional reclosing scheme.
- The significance of this scheme is that it can be implemented for online application because it not need for relevant large amount of calculation.
- Does not need any artificial intelligent techniques.

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