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# Modeling and Simulation of a Solid-State Breakers in Electric Power Distribution Systems by Using GUI-Based Environment of MATLAB/SIMULINK

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## ABSTRACT

**This paper proposes detail of formulating solid-state breakers (SSB) in electric power distribution systems by using GUI-based environment of MATLAB/SIMULINK. Utilization of MATLAB software simplifies problem-solving complexity and also reduces working time. In this paper, a 22-kV power distribution feeder with a load having the SSB for protection is situated. A thyristor-based circuit breaker is modeled. Detail of the power circuit and its firing control part is demonstrated in graphical diagrams using elements of the MATLAB's Power System Blockset (PSB). Test against a fault condition to verify its use is carried out. The results show that, with a moderate sensing technique to monitor voltage and current of the protected feeder, the SSB can interrupt fault instantaneously.**

***Keywords:*** **Solid-state breaker, Thyristor-based switch, MATLAB/SIMULINK, Power system blockset**

## I. INTRODUCTION

With the growing of demand of electric power, the distribution system is expanding continuously. This results in the high level of short-circuit currents. Therefore, the electric distribution cost such as devices, installation, operation and maintenance increases gradually. Moreover, the high level of short circuit current becomes the serious problem. It may damage the electric devices or effect on machine operation. Continuity of power supply systems is very low because operations of protective devices under faulted conditions. Mechanical circuit breakers in power distribution systems give a safe handling of short-circuits under limited short-circuit power of the grid. Using delayed turn-off times, the circuit breakers can be coordinated with some other protective equipment. Hence, a high availability of the grid can be expected. However, when the short circuit event occurs in a medium-voltage distribution feeder, voltages along the feeder line are suddenly sagged. Sensitive loads such as computers or electronic-control equipment will fail even if the voltage returns within a few seconds. A solid-state circuit breaker [1-3] is able to switch at very high speed as fast as voltage or current sensing devices can response to the faulty signal. In this paper, a simple thyristor-based circuit breaker is briefly reviewed. Modeling using Power System Blockset [4] considering the requirements of a solid-state switch integrated into a 22-kV medium voltage distribution feeder is demonstrated. Based on the thyristor characteristics, triggering signal generation for firing control is also explained. It shows that solid-state breakers offer very fast interruption and can be used in modern medium voltage power distribution systems.

## II. PSB MODEL OF A SOLID-STATE BREAKER

Figure 1 shows a feeder circuit breaker of mechanical and solid-state types. Present designs of distribution feeder protection rely on expulsion fuses, which have to be reset manually. An SBB is used to protect sensitive loads by interrupting it if there exists a system fault on the supply feeder. This can be incorporated using thyristors [1].

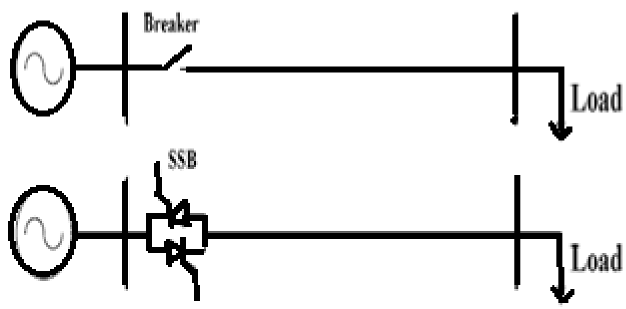



Fig.1 Feeder circuit barkers

The solid-state breaker is designed using thyristors because the switch requires a continuous current carrying and a short time over current rating equal to the feeder faults level. Thyristors have a short time rating up to 16-kA and also have low conduction losses [1]. The thyristors in the feeder are normally energized by continuous and synchronized firing control signal. On detection of voltage sags, these firing ulses are stopped to break the current. Fig. 2 explains the control structure of the SSB.

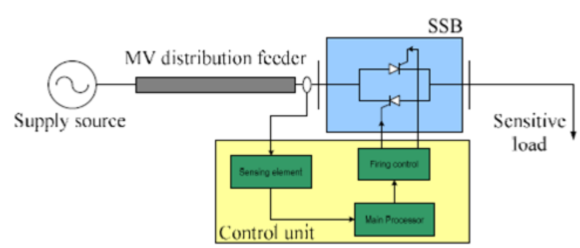



Fig.2 Control structure of the SSB

MATLAB's power system blockset (PSB) is a GUIbased tool for simulation works on power systems with power-electronic control. To create the SSB as described previously, a set of two thyristors connecting in anti-parallel fashion is required. It can be represented in a SIMULINK model using PSB as shown in Fig. 3. Line-In and Lineout are two power ports connected to the supply side and the load side, respectively. Control fw and Control bw are two signal ports that transfer the firing signals to the upper and lower thyristors, respectively. The SSB block is controlled by signals from a firing controller. Fig. 4 shows a combination of the proposed SSB with some other PSB models to simulate a medium-voltage power feeder operating under the fault condition.

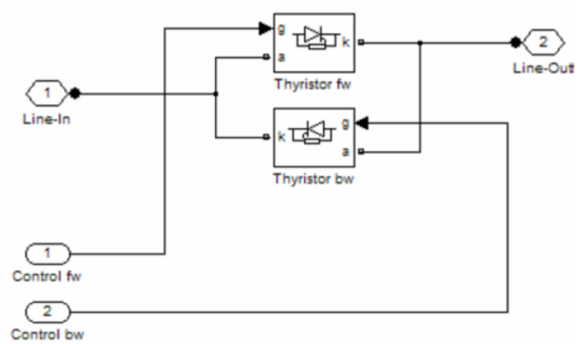



Fig..3 SIMULINK model for an SSB (SSB-1ph)

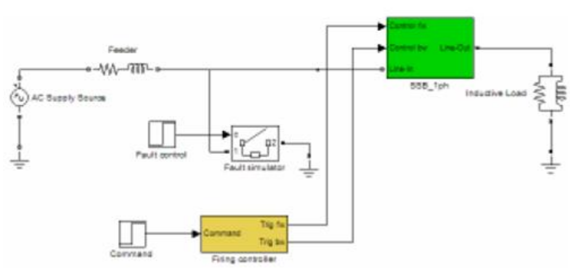



Fig.4 SIMULINK model for an MV power feeder with an SSB

## II. Firing Control

To generate firing signals to turn on the thyristors, a saw-tooth signal with a DC reference signal are compared. The result is the pulse signal used in the SSB block. The firing control block diagram created in SIMULINK is given in Fig. 5.

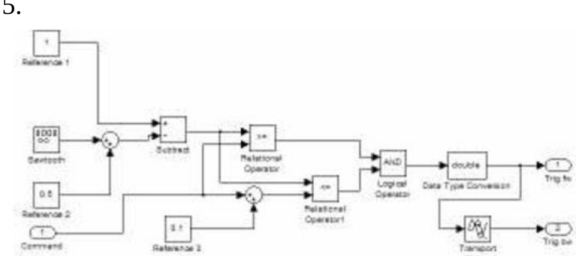


Fig. 5 SIMULINK model for a firing controller

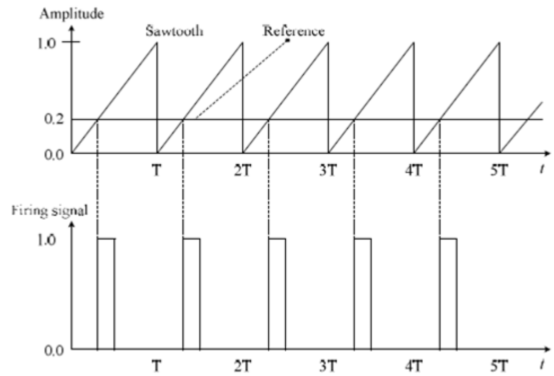



Fig. 6 Firing signal generated from the firing control

## IV. Voltage Detection Scheme

Firing strategy to the SSB has only one objective. It is to allow full current flowing to the load. The firing angle for this case is set to zero degree. When a fault occurs, the short-circuit current must be interrupted as fast as possible. To switch off the SSB, the firing angle is set to 180 degree. To change the command to the firing control unit requires a voltage sensing device. In this work, rms voltage detection is used to monitor the voltage sag of the load. Fig. 7 shows the block diagram of rms voltage detection used for the SSB application.

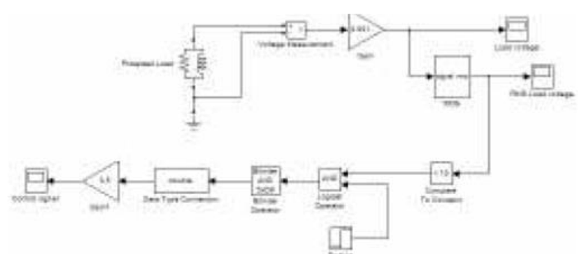
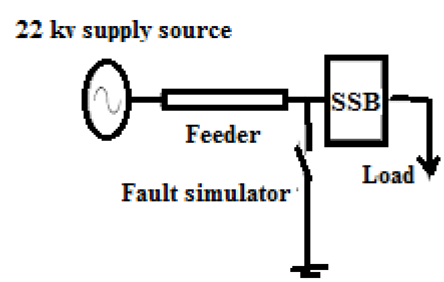


Fig.7 RMS voltage detection

## V. Simulation Results

A 22-kV distribution feeder serving the load of 200 kW, 150 kvar is created in SIMULINK as shown in Fig. 8. It assumes that a short-circuit event occurs at t = 0.16 s. The test case scenario performs with a time span of 0.2 s.




(a) Test system

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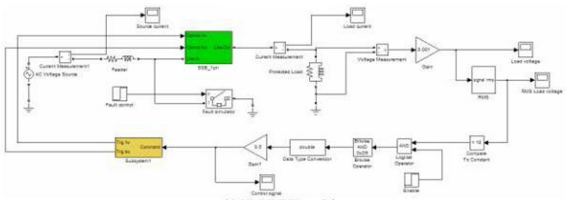
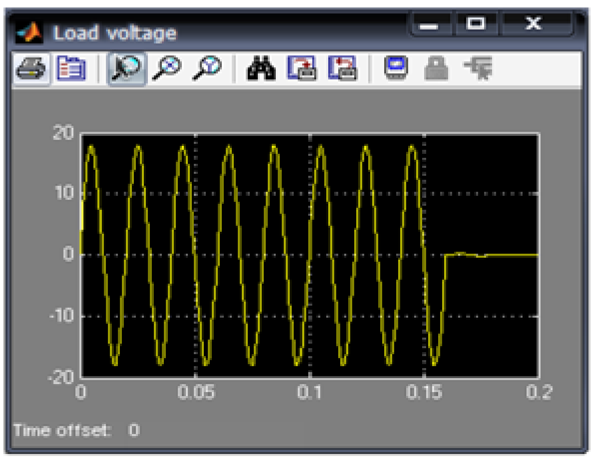


(b) SIMULINK model

Fig. 8 SIMULINK model of the test feeder

It takes the first cycle for the rms value reaching its actual rms voltage. When the fault happens at t = 0.16 s, the load voltage drops to the value close to zero as shown in Fig. 9. The rms value for the load voltage can be presented in Fig. 10.




Fir. 9 Load voltage (kv)

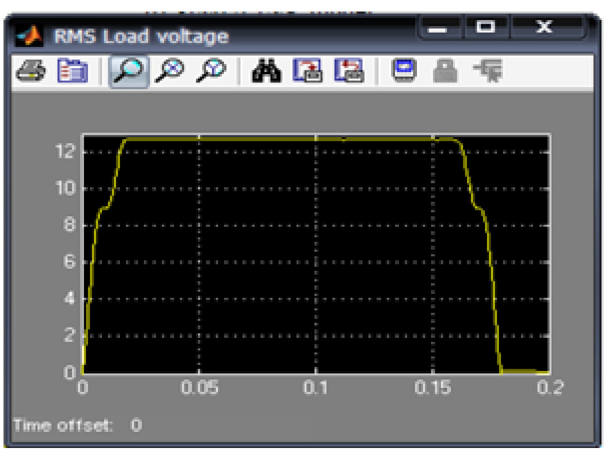



Fig. 10 RMS load voltage (kv)

To verify that the SSB can interrupt the fault current effectively, the currents supplied by the source and drawn by the load are recorded. Fig. 11 gives information of the source current. This figure intentionally indicates the current during the fault event. Fig. 12 explains the current drawn by the load at the normal loading condition.

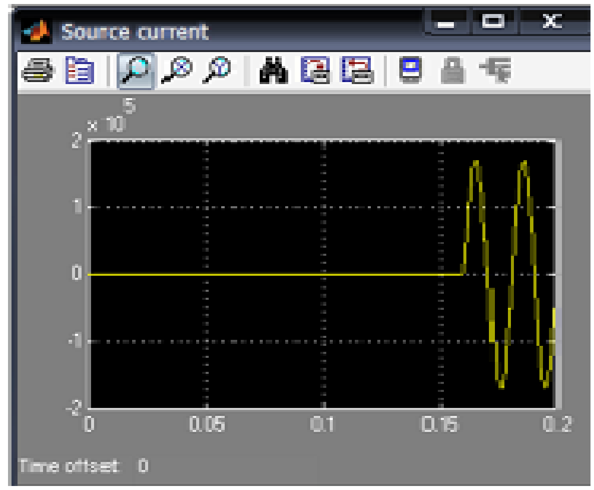



Fig. 11 Source current (A)

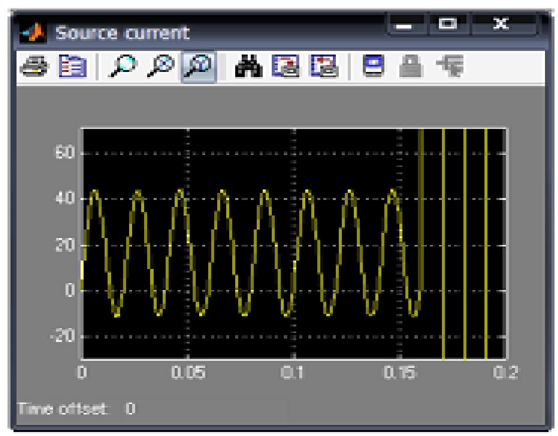



Fig.12 Source current (A) ,zoom in version

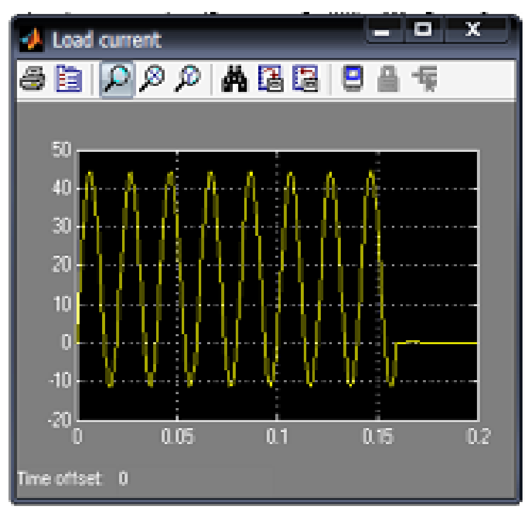



Fig 13 load current (A)

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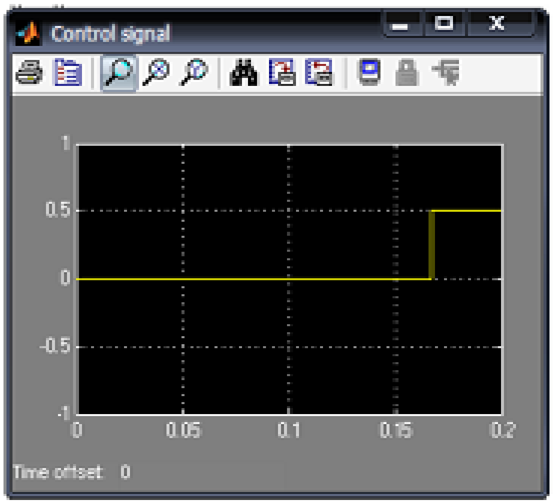


Fig. 14 Command singnal

The load current responses can be shown in Fig. 13. From the figure, it can notice the DC component when operating at the normal load condition. The maximum positive peak current is just over 40 A. It can be seen that the SSB can successfully interrupt the fault current. Zeroing load current in the figure can support this reason. In addition, the firing command as shown in Fig. 14 shows the transition of the SSB status from turn on to completely turn-off for interrupting the fault current. During the fault the load current has no DC component.

## VI. Conclusion

This paper proposes detail of formulating solid-state breakers (SSB) in electric power distribution systems by using GUI-based environment of MATLAB/SIMULINK. In this paper, a 22-kV power distribution feeder with a load having the SSB for protection is situated. Test against a fault condition to verify its use is carried out. As a result, with an appropriate sensing technique to monitor voltage and current of the protected feeder, the SSB can interrupt fault instantaneously.

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