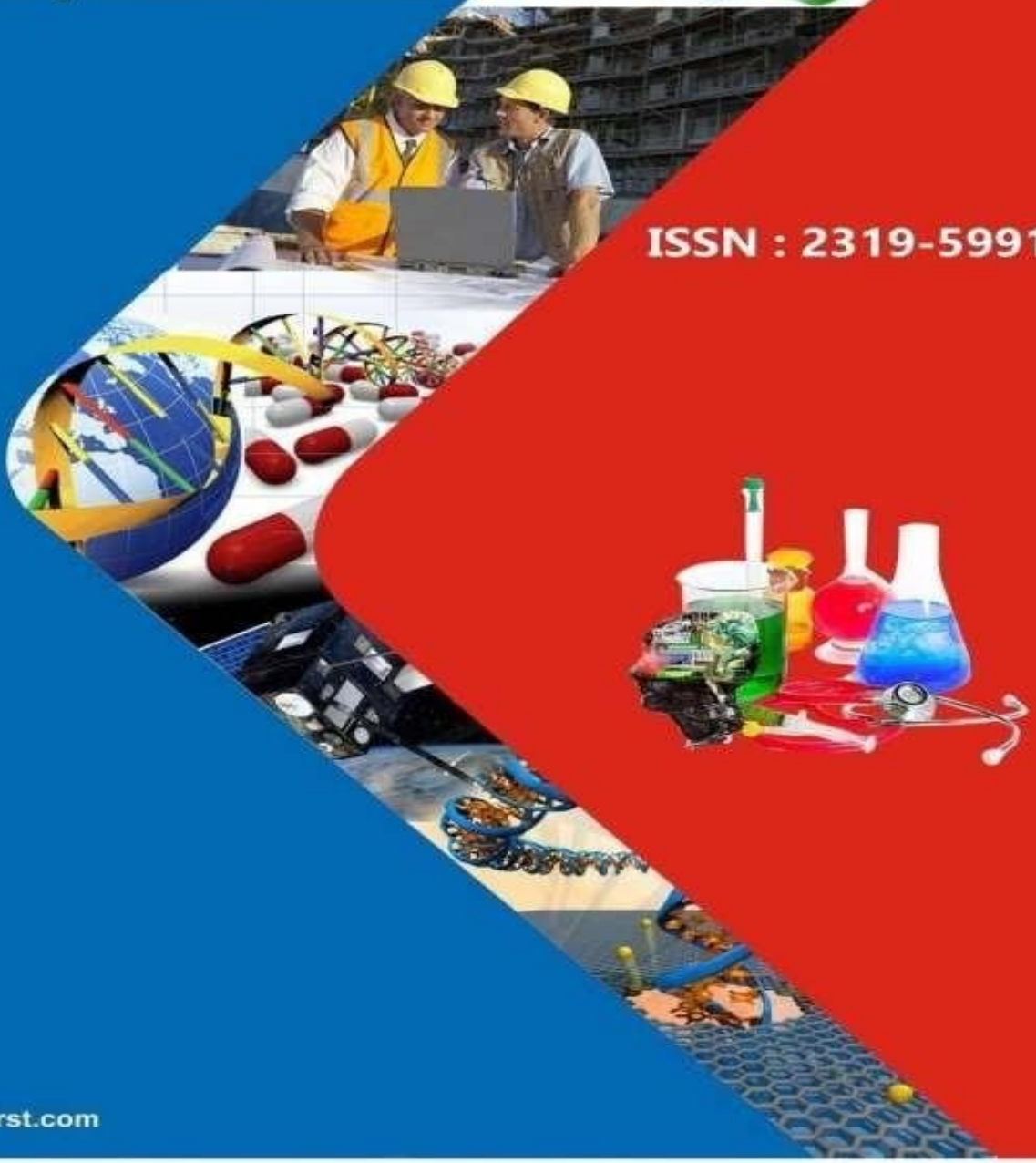
International Journal of Engineering Research and Science & Technology

IJERST

ISSN : 2319-5991



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International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com

Vol. 21, Issue 2, 2025

Simulink Modelling For Mitigating Technological Disruptions In Power System

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Abstract

Even when instrument transformers fail, modern PSP systems can capture the exact measurements. Insights about algorithm performance and optimal trigger configurations for individual security systems and automations may be gleaned from this. But electromechanical and thermal impacts may harm or destroy the equipment if the settings are wrong. By fine-tuning parameters, the simulation modeling approach may aid in avoiding such problems. The authors of this study examined the practicality of their simulation model for a 110 kV power line used for transit, which is fed by 220 kV substation buses and has a number of protective devices attached to it. During the emergency shutdown of a 110 kV power line in the Voronezh Oblast, the data from the AURA was used to evaluate the applicability.

SCIENTIFIC NOVELTY OF THE ARTICLE

There is continual variation in the characteristics of an electric power system, which makes it a complex system [5]. For example, current and voltage values in various areas of the power system might increase or decrease, and frequency dips can occur, among other things, during short circuits. Estimating the changes in different parameters during emergency modes and making predictions about them is therefore a challenging task. It could take many hours to calculate one emergency mode in order to get voltage and current measurements at various places in the power system [6]. This necessitates the development of precise models capable of delivering voltage and current values for various components of the power system. Electronic power grid, digital substation, automation and protection of relays, digital technology, cluster, digitization, Simulink

INTRODUCTION

One of the most encouraging ways to study power plants is via simulation modeling. One of the most essential problems for power engineers is modeling the operational algorithms of PSP systems, as these systems are crucial to power systems [1]. Building a model that can accurately simulate a power unit's functioning using realistic parameters is the main objective of modeling. You may investigate a facility in this manner without having to pay for the actual construction of it, [2]. Digital protection terminals are used by modern substations. Because of this, models may be used for theoretical calculations of certain parts of the power system and operating modes, and they can also be used to program terminals further while considering all the bugs found during modeling [3]. Building a model for a 110 kV power line that terminates at a dead end using electricity from 110 kV substation buses and a series of protective devices is, therefore, the primary objective of this work [4]. Our next objective was to determine if this model could be used in actual facilities. An actual emergency, the cutting of a 110 kV power line in the Voronezh Oblast, necessitated the use of this data for the study. Accurately simulating the real-life facilities is the main challenge in developing models. In spite of this, Simulink models proved time and time again that they could provide very accurate indications, [7]. The model of the high voltage transmission line protection system that is built is what makes this research distinctive. There were theoretical calculations and models of various system modes of functioning in earlier scientific publications [8]. The

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ISSN 2319-5991 www.ijerst.com
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data collected from actual devices during a technological disruption is compared with the outcomes of simulation modeling in this research.

DESCRIPTION OF THE MODEL

The modelled power line terminates in a dead end between two 110 kV substations, as previously stated. The modeled power line, however, must be supplied by the 110 kV buses of the Opornaya substation, which in turn must be powered by the 220 kV Pridonskaya substation, according to the system design [9]. As shown in figure 1, the grid diagram includes the electricity line that has been modelled. The 110 kV power line specifications between Opornaya and Radchensky are: 1) The cable is 37 km long; 2) it is AS-185 brand; and 3) it is installed on a single-circuit tower with a diameter of 5 m.

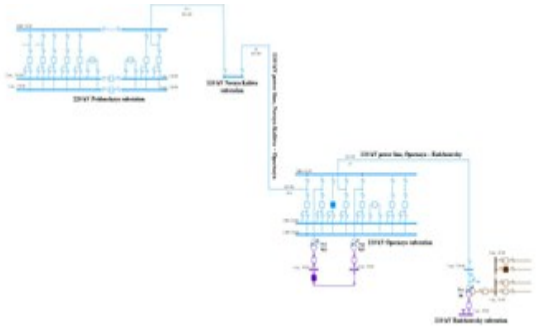


Fig. 1. The grid section in the Voronezh Oblast.

The AURA data collected during the 110 kV power line breakdown is included in the example data (fig. 2). Phase A of the 110 kV electricity line between Opornaya and Radchensky had a flashover, according to the following study.

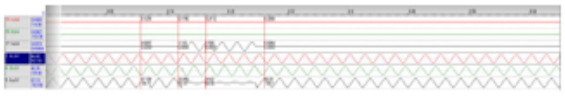


Fig. 2. The AURA oscillograms.

An emergency data file in either the AURA or COMTRADE format may be used by the AURA recorders to document emergency procedures [10]. Automated processing of the generated files is possible. On top of that, newer recorders come with a variety of connection options and even let you browse the assembled files remotely using an Ethernet network. A single-board computer (SBC) without a cooling system, an interface box (IB) with a 12-digit analog-to-digit converter (ADC), and signal switching blocks make up the system unit, which is an aluminum-profile enclosure that can withstand vibrations. See the AURA unit from the outside looking in in Fig. 3.



Fig. 3. Exterior view of the AURA unit.

A single-phase line-to-ground short-circuit caused by the phase A cable of the 110 kV power line flashing over was determined to be the cause of the breakdown, according to the inquiry [11]. Oscillogram analysis reveals that the SC was active for 0.125 sec., the damaged section shut down in 0.28 sec., the SC current reached 1.5 kA, and the ACR went into withdrawal mode. As far as the Opornaya 110 kV substation is concerned, the switch is MMO 110. Table 1 displays the PSP configuration.

TABLE I. Name PSP SETTINGS ON THE OPORNAYA 110 KV SUBSTATION FOR THE 110 KV POWER LINE OF RADCHENSKY

Name	Value	Delay, t
RP (Stage I)	21.2	0.1
RP (Stage II)	39.3	0.5
RP (Stage III)	85	4.0
TO	2100	0.1
ACR	-	withdrawn

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DESCRIPTION OF THE DEVELOPED

It follows that the damage triggered the RP Stage 1 to shut down after 0.1 seconds. At 0.2 seconds, however, the oscillograms reveal that the switch was disabled. The speed of signal transmission and the time it takes for the switch to trigger explain this [12]. Prolonged use somewhat increased the rated switch shutdown time of 0.08 seconds [13]. The predicted fault site, according to the remote protection system, was 20 kilometers away from the Opornaya 110 kV substation. We built the power system section model in Simulink using the schematic in figure 1. Figure 4 shows its single line diagram. Following the single-line connection schematic, the constructed simulation model is shown in Fig. 5, along with the major components of the power system.

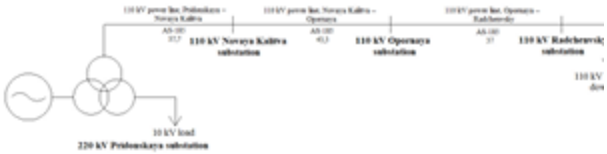


Fig. 4. The single-line diagram of the model.

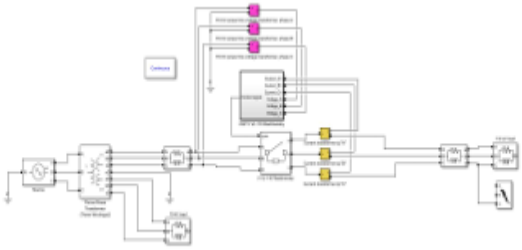


Fig. 5. The Simulink model diagram.

It uses the Simulink application's basic blocks as a foundation, but these equations were used to determine the power line parameters:

$$X_l = x_0 \cdot l \qquad (1)$$

$$L_l = \frac{X_l}{2\pi f} \qquad (2)$$

The following procedure was used while adjusting the transformer parameters: [14]. 1) Finding the voltage across the short circuit of every winding:

$$U_{kB\%} = 0.5 \cdot (U_{kB-C\%} + U_{kB-H\%} - U_{kC-H\%}), \qquad (3)$$

$$U_{kC\%} = 0.5 \cdot (U_{kB-C\%} + U_{kC-H\%} - U_{kB-C\%}), \qquad (4)$$

$$U_{kH\%} = 0.5 \cdot (U_{kC-H\%} + U_{kB-H\%} - U_{kB-C\%}). \qquad (5)$$

Assigning values to the quantities for high voltage, medium voltage, and low voltage windings, respectively, are indices B (1), C (2), and H (3). With an active-inductive load of around 13.1 MVA, the 10 kV consumer model is put into action with the help of the Series RLC Load block. The block for configuring the 10 kV load is shown in Figure 6. Consequently, a model of both main equipment and RPA circuits has been constructed using standard Simulink blocks, [15]. This example of an RPA circuit includes voltage and current sensors, along with the VL-110 S-z Radchensky protection unit's logical component. Note that the idealized sensor model could explain why the model study's measurements of network operating parameters don't match up with data from actual current and voltage transformers.

A three-phase transformer with three windings is shown in Fig. 7.

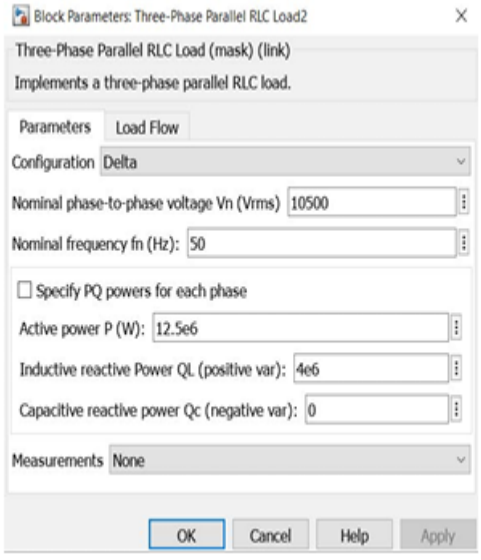


Fig. 6. 10 kV load reference unit.

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ISSN 2319-5991 www.ijerst.com

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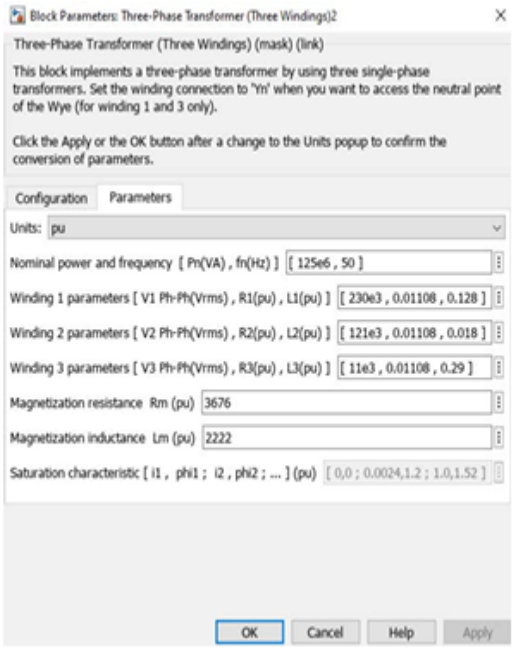


Fig. 7. Power transformer unit parameters.

Mathematical models of monitoring current and voltage transformers pose significant computational challenges due to the large number of real-world factors involved. The winding resistance, magnetization properties, and transformation ratio of current transformers are all variables that are often off [16]. Simulink, on the other hand, makes use of idealized current and voltage sensors; that is, it gauges the parameters of the network's functioning independently of each other [17]. An integral part of the model is the PSP V VL-110 Radchensky block, which models the algorithms used by the PSP systems placed at the 110 kV power line connection between Opornaya and Radchensky, as well as the 110 kV Opornaya substation. The present cutoff and remote protection stages I and II's operation algorithms are modeled in this study. The actual substation parameters (Table I) were used to choose the settings. The Radchensky block of PSP V VL-110 is seen in Fig. 8.

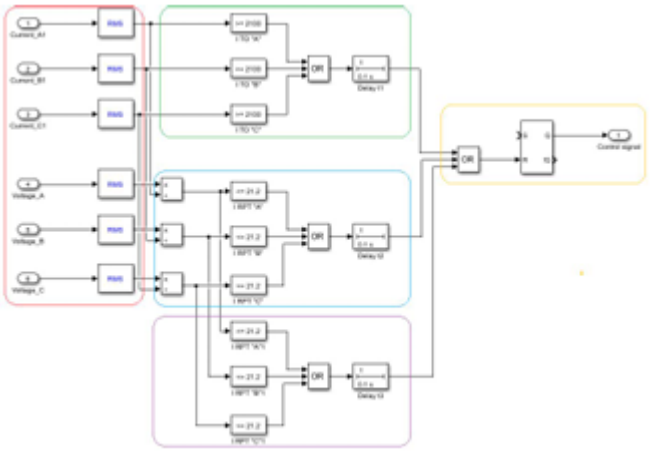


Fig. 8. The PSP V VL-110 Radchensky block.

The VL-110 S-z Radchensky relay protection unit model, like the actual equipment, is conditionally divided into six major elements (Fig. 8). - The red-highlighted power section receives signals from voltage and current measuring transformers; - The green section is the logic side of the current cutoff and compares data from the measuring transformers to the setpoint; – Finally, the green section is the logic side of the current cutoff. - blue - the logical component of the I stage line distance protection, which verifies the fulfillment of the conditional setpoint condition and the preset setpoint; moreover, the time delay is accomplished. In the same section of the unit, you can find the time delay calculation, and it also verifies whether the conditional resistance Z setpoint condition is satisfied. The blue section represents the logic component of the first stage of line distance protection, which is responsible for the time delay; the purple section represents the logic component of the second stage of line remote protection, which also performs similar functions; and the orange section is the component that transmits the control signal and has the trigger. Section V: Findings from the Research The technical fault investigation's findings indicated that the 110 kV Opornaya substation's buses were located around 20 kilometers distant from the problem site. Therefore, we simulated a short-circuit 20 km distant from the V VL-110 Radchensky using the values of l=20 km in equations (1) and (2) to evaluate the model's sufficiency. In figure 9, you can see the oscillograms that were acquired. By examining the acquired oscillograms, we may ascertain the following values that can be used to ascertain the types of protection that were triggered, the magnitude of the voltage drop in the bus section,

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and the currents that occurred during the short circuit: [18]. The 110 kV power line from Opornaya to Radchenvsky had a stable phase A current value of 1,560 A, and the current values in phases B and C are the same as the current values during normal operation.

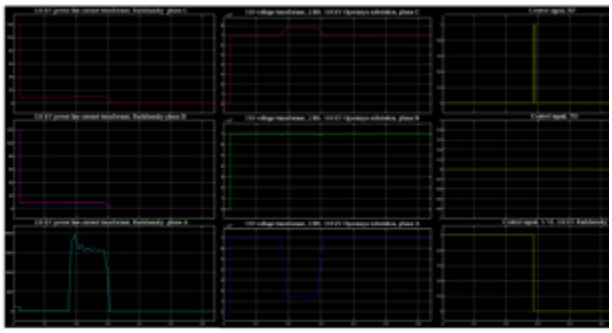


Fig. 9. The oscillograms obtained during the short-circuit

twenty kilometers from the Radchensky VL-110. In terms of the voltage values in the two bus sections of the 110 kV Opornaya substation, there was a 10% rise in phase C, some fluctuation but no change in phase B, and a decrease to 14.43 kV in phase A when the short-circuit current passed. In addition, the remote power line protection method was used, leading to a switch shutdown, as seen in the accompanying graphs [19]. Concurrently, the control signal from the present cutoff was unaltered, [20]. As a result, the calculated values are in agreement with the AURA data, and the observed parameter discrepancies amount to 3.8% current and 2.7% voltage. These numbers show that the established model is rather adequate. A random resistance Z, defined as the ratio of the substation bus voltage to the connection current, is shown in Fig. 10 together with its corresponding oscillograms. The power line may be remotely protected using this setting. Consequently, this characteristic aids in determining the distance from the feeder substation busses to the place of short circuit. At 9.16 p.u., the resistance has a stable value. This figure is equivalent to 22.18 kilometers when recalculated to get the fault location. This is an error of 10.9%. Keep in mind that in practical situations, remote protection could not always provide an accurate problem location, with an error rate of up to 10-15%. Several things, like the surrounding air temperature, the amount of precipitation, the insulation levels, etc., might cause this. Given the relatively high voltage class and substantial power flows, the absence of modeling the internal features of the current and voltage measuring transformers also has a major influence.

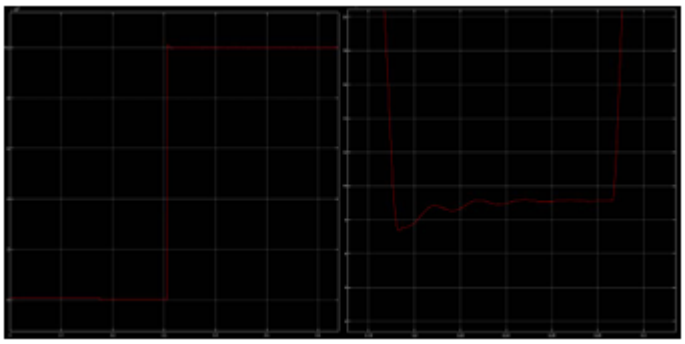


Fig. 10. The oscillogram of the arbitrary resistance Z.

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To review, it is important to mention that the model that was created showed great adequacy, which means that it may be used, or one like it, to simulate and calculate different operating modes of a power system segment. The results from the research using the created Simulink model were compared with the AURA data captured during an actual technical failure in a 110 kV power line, confirming this. The potential for integrated data retrieval from instrument transformers situated at different positions within the power system section during faults may be realized via the continued development of this model. The usage of Simulink models allows for the prediction of system behavior in a variety of contexts, as well as the testing and optimization of control and protection measures. As a result, engineers may save time and money while designing and implementing new power supply systems by doing virtual testing. When it comes to solving various energy-related problems, power transmission line modeling in Simulink is a crucial tool for making sure power supply systems are reliable and efficient.

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