Simulation tutorial in ATPDraw™ software for Lateral Branch Switching, Lumped Load, Distributed Load and Capacitor Switching in distribution systems

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Abstract—This tutorial paper provides a comprehensive guide on performing switching operations in distribution systems using ATPDraw™ software. The focus is on understanding the appropriate modeling and simulation techniques for various types of load switching events in electrical distribution systems. The tutorial covers key aspects such as lateral branch switching, lumped load, distributed load, capacitor, and non-linear load. By acquiring a thorough understanding of these switching operations, researchers and practitioners can effectively study and analyze electrical distribution systems. Having the knowledge and skills to accurately model and simulate switching events is crucial for conducting in-depth studies related to energy distribution. This tutorial serves as a valuable resource for researchers and professionals seeking to enhance their understanding and proficiency in modeling and simulating switching operations in electrical distribution systems.

Keywords—ATPDraw™ software Tutorial, Distribution System, Lateral Branch Switching, Lumped Load Switching, Distributed Load Switching, Capacitor Switching.

I. INTRODUCTION

The Electric Power System (EPS) plays a critical role in the transmission and distribution of electrical power and therefore requires efficient fault detection mechanisms [1, 2]. A major challenge in EPS is the detection of faults such as high impedance faults (HIFs) and conductor breaks [3, 4, 5]. To overcome this challenge, ATPDraw™ software has become widely used for EPS simulation and analysis [6], enabling accurate modeling distribution systems [7, 8, 9].

However, despite the software's capabilities, there is a lack of practical guidance to help users effectively use ATPDraw™ for EPS modeling. This gap hinders the dissemination of knowledge and makes it difficult to perform accurate studies in practice [10]. Therefore, this paper aims to fill this gap by providing comprehensive guidelines for modeling EPS with ATPDraw™. The goal of this paper is to provide electrical engineering professionals and academics with the tools and knowledge necessary to effectively model EPS using ATPDraw™. Through practical insights and step-by-step instructions, the paper aims to improve the understanding and use of the software and ultimately contribute to a more reliable and stable electrical power supply.

Using the guidelines presented, readers will gain valuable insight into the modeling process so they can accurately simulate and analyze EPS behavior. This understanding is essential for identifying and detecting faults, ensuring that immediate action is taken to mitigate faults and minimize downtime in electrical distribution systems.

One of the major challenges in energy distribution systems is the detection and distinction of conductor breaks (CBs) in electrical systems [9]. When a CB occurs and a conductor comes into contact with a high impedance surface such as concrete, asphalt, sand, or vegetation, it can lead to a High Impedance Fault (HIF), which is typically difficult to reliably detect and distinguish from other common events in the network. These situations pose risks to human life and property [3, 4, 5]. Moreover, due to the extremely low current associated with this type of fault, conventional protection schemes fail to activate, as they require a significantly higher current threshold [4]. Therefore, the importance of detecting and distinguishing this phenomenon in distribution systems becomes evident, as it should not be confused with other common events such as Lateral Branch Switching (LBS), Lumped Load Switching (LLS), Distributed Load Switching (DLS) and Capacitor Switching (CS).

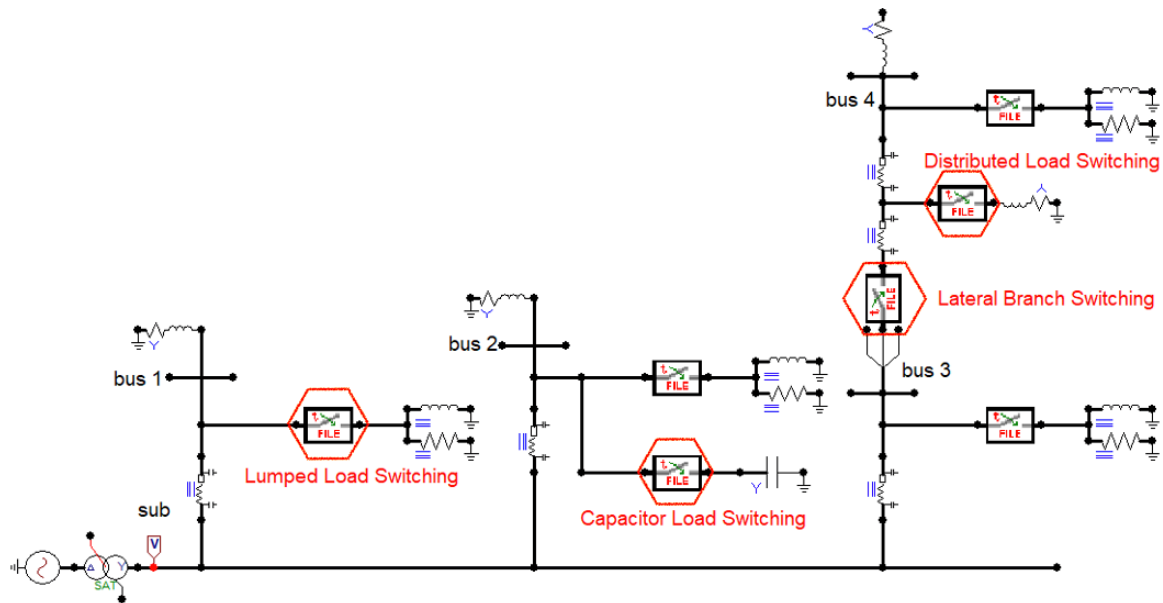Contact data: Pedro Henrique Pereira de Oliveira, oliveira.henrique@uft.edu.br

Fig. 1: Model for lateral branch switching.

In summary, this paper fills a gap by providing a comprehensive guide to modeling EPS with ATPDraw™. By disseminating this knowledge, it is hoped that electrical engineering professionals and researchers will be able to realize the full potential of ATPDraw™ for accurate EPS simulations and effective fault detection in transmission and distribution systems.

II. STATE OF ART

The ATPDraw™ software, a freely available tool for electromagnetic studies, enables accurate modeling of electrical systems encompassing generation, transmission, and distribution within a unified platform [6]. A highly sought-after paper on ResearchGate [online] [11] presents simulations conducted using ATPDraw™, surpassing 5 thousand accesses. Another tutorial [10] emphasizes how to install the software, parameter modeling, and interpretation of results using a 4 node test feeder system [10]. Using the same test feeder [7], explains waveform plotting techniques for voltage and current through ATPDraw™.

Most works utilizing ATPDraw™ focus on showcasing results rather than providing detailed insights into system simulations, highlighting the need for further research and development in utilizing the software for distribution system modeling across various domains. By expanding the study of ATPDraw™ in all areas, significant contributions can be made to society's understanding of electrical systems.

III. TUTORIAL

This section addresses the four types of switching discussed in this paper, each of which plays a central role in the effective operation of distribution systems. Switching is a critical process in the management of electrical power and plays a central role in optimizing power flow and minimizing losses. These four types of switching are also applied in several previous studies, as mentioned in [9, 12, 13, 14, 15] . In this section, the focus is on studying in detail how these switching operations are performed in practice. This provides valuable insight for electrical engineering professionals who wish to improve their skills in modeling and simulating distribution systems using ATPDraw™ software.

Figure 1 shows a 5 bus distribution system feeder [13] in which the Models [14], associated with the four types of switching discussed in this article, can be clearly seen: Lateral Branch Switching (LBS), Lumped Load Switching (LLS), Distributed Load Switching (DLS), and Capacitor Switching (CS). Each of these four switching scenarios is examined in the following subsections to show their relevance to distribution system studies.

a. Lateral Branch Switching (LBS)

The concept of Lateral Branch Switching (LBS) involves the selective switching on and off of a lateral branch within the power system. This controlled action results in significant changes in voltage and current signals, even when the event occurs at a considerable distance from the metering point. LBS Events cause dynamic changes in the distribution system and often trigger changes in load characteristics and energy flows. The ability to accurately model and simulate LBS scenarios with ATPDraw™ is critical to understanding the resulting impact on system behavior[9, 12]. Thus, to simulate the LBS in ATPDraw™, just put the Model tool [14, 16] at the point where you want to perform the switching, as shown in Fig. 1, and the code shown in Fig. 2 must be entered in the Model Editor [14].

It should be noted that this Fig. 2 shows an example of the Lateral branch Switching code, however, the same can be replicated for the other cases: LLS, DLC and CB.

Next, a detailed analysis of Fig. 2 is presented with a line-by-line explanation. The goal is to provide a deeper understanding of the code required to properly execute the switch within the ATPDraw™ environment.

Line 1: This line introduces the Lateral Branch Switching (LBS) example as a Model that clearly relates to what this

Fig. 2: Lateral branch switching code example.

part of the code will illustrate.

Line 3: This line defines the **OUTPUT** signals of the LBS example as "output1"," "output2" and "output3". These signals represent the results or changes that occur due to the LBS operation.

Line 4: The keyword **VAR** is used here to declare the variables "output1"," "output2"," "output3" and "index" These variables are used throughout the code to store and manipulate information.

Line 6: This line introduces the definition of a **FUNCTION**, in this case, called "timeSW POINTLIST" This function is critical for simulating the LBS scenario and its dynamics.

Line 7: Here, an external file named "LBS.txt" is included with the command **INCLUDE**. This file contains the necessary parameters for the simulation of Lateral Branch Switching (LBS). Figure 3 shows all the corresponding .txt files for the distribution network in question (5-bus feeder). Each inserted switching event corresponds to a separate .txt file."

Lines 9-14: The **INIT** and **ENDINIT** block encapsulates the initialization of variables and history functions within the Model. In this segment, the initial values of the variables are assigned. "index" is set to 1 and "output1"," "output2" and "output3" are initialized to 1.

Lines 16-25: This block, marked **EXEC** and **ENDEXEC**, encapsulates the main content that will be executed during the simulation. It contains conditional operations and calculations. When the time "t" exceeds the time specified in "timeSW(index)"," the conditional instructions inside the block "IF" are executed. Here the states of "output1"," "output2" and "output3" are changed depending on certain conditions and increments of "index"

Line 26: The **ENDMODEL** statement concludes the definition of the Lateral Branch Switching (LBS) model.
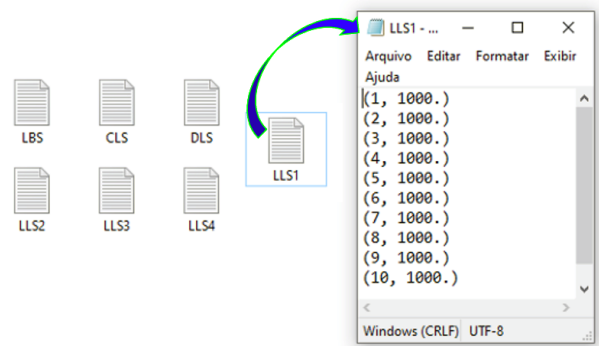

Fig. 3: .txt files example.

This comprehensive explanation describes the purpose and operation of each line of code so that the reader can understand the step-by-step process of the switching in ATPDraw™ software.

b. Lumped Load Switching (LLS)

Switching, that is adding and removing a lumped load in one of the phases, may cause the protection devices to misidentify, for example, a conductor break [9, 12]. Therefore, simulating this switching is extremely important for testing in electrical energy distribution systems [13]. To simulate lumped load switching, just insert the switching Model in the branch of the system where you want to switch, as shown in Fig 1.

Figure 2 shows the code that must be inserted into Model to simulate *LBS*, but as mentioned earlier, the same code is used for the *LLS* case.

c. Distributed Load Switching (DLS)

The process of Distributed Load Switching involves adding and removing loads that are spread across the three phases. This action has the potential to cause inaccuracies and errors in the protective devices measurements [9, 12]. Figure 1 shows the integration of the switch into the system using the Model tool [13, 14], and the Fig. 2 displays the code implementation for the switching operation.

d. Capacitor Switching (CS)

Most of the literature on high impedance fault and conductor break detection shows that switching capacitors is one of the factors responsible for erroneously detecting some disturbances that may occur in the electrical system [9, 12, 13]. For this reason, this CS is of paramount importance in the study of distribution system protection. Similar to the previous cases, Fig.1 highlights the switch inserted into the system to execute the *CS*, and Fig. 2 the code of the switch is shown.

e. Closing Remarks

Switching operations play a critical role in distribution system studies because they can affect protection systems and cause interruptions in the power supply to loads. Just as the four types of switching operations were demonstrated in this tutorial, several other types of switching operations can be performed to enhance the understanding of distribution system simulations. Examples of other types of switching operations include switching non-linear loads, switching linear loads, switching on transformers, and switching variable rectifiers. Understanding these operations is essential to maintaining a reliable and high quality electrical distribution system.

IV. CONCLUSIONS

Mastering simulations of switching operations in distribution systems with ATPDraw™ enables researchers and professionals to delve into the intricacies of power distribution. This textbook provides them with the indispensable skills for accurate modeling and promotes a deeper understanding of system dynamics. As energy systems become increasingly complex, this knowledge is of paramount importance.

a. Future Work

Exploring advanced switching strategies, integrating renewable energy sources, and investigating the impact of switching operations on system stability and power quality are promising avenues for future research. In addition, the development of adaptive protection systems to mitigate problems caused by switching operations and the extension of the study to new technologies can further improve the understanding and effectiveness of distribution systems.

V. ACKNOWLEDGMENT

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