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Distance Modelling for Compensated Transmission Line

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This paper focuses on the analysis of non-uniform transmission lines with distributed line parameters that vary along the length of the line. The objective is to develop a method to analyze such transmission lines using the perturbation technique. The proposed method utilizes Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL) to establish a system of coupled first-order linear differential equations for the voltage and current along the line. These equations have non-constant coefficients due to the inhomogeneity of the line. To implement the perturbation method, the original system of coupled differential equations is expanded using state variables, where the state vector comprises the voltage and current variables along the line. This research contributes to the field of transmission line analysis by providing a method for analyzing non-uniform transmission lines with varying distributed parameters. The perturbation technique offers a powerful tool to approximate the solutions of the coupled differential equations, enabling engineers to understand and design transmission lines more effectively. The findings presented in this paper can be applied to various areas such as power systems, telecommunications, and signal transmission, where non-uniform transmission lines play a crucial role. Future research could explore the extension of this method to address non-linear dependencies and randomly fluctuating parameters, broadening the scope of its applicability.
Keywords: non-uniform Transmission line, KCL, KVL, modelling, series capacitor etc.

1. Introduction

The rising demand for electricity leads to a rapid expansion of the transmission system and an increase in the amount of power that must be transferred before the transmission line reaches its thermal limit. Series compensation will be installed on long EHV transmission lines as a result of this. End-line compensation and mid-line compensation are employed in practise depending on the location of the compensating device on the circuit.

Understanding the influence of series compensation on protection is essential to designing acceptable systems for utility networks employing series capacitors. For high-power EHV transmission lines, distance relays are often used for protection purposes, and compensation is typically implemented in a transmission system. A distance relay uses real-time measurements and fault type information to calculate the line's impedance in real time. The impedance of a series compensated transmission line is affected by the addition of a compensating device. Because of this, the precise position of the problem in relation to the compensator, which in turn increases the availability and stability of the system. As a consequence of this, the system's transient stability as well as its switching overvoltage will be enhanced.

An electromagnetic transmission line is a kind of cable or other structure that is specifically built to transmit electromagnetic waves. It's referred to when the length of the conductors necessitates consideration of wave nature. The small wavelengths used in radio-frequency engineering imply that wave phenomena may occur over extremely short distances, making this a particularly relevant consideration (this can be as short as millimetres depending on frequency). When it comes to long-distance telegraph lines, such as undersea cables, the idea of transmission lines was first devised to explain occurrences.

Transmitting lines are used for a variety of applications, including spreading cable television signals, transmitting phone calls between switching centres, and transmitting high-speed data over computer network connections and high-speed computer data buses. There are several ways to design circuits using RF transmission lines, including using printed planar transmission lines and arranging them in certain patterns. distributed-element circuits are an alternative to typical circuits that use discrete capacitor and inductor components.

Low-frequency alternating current (AC) and audio signals may be carried using standard electrical wires. Radio frequency currents beyond 30 kHz cannot be carried by these cables due to the energy being radiated off the cable as radio waves, resulting in power losses. Connectors and junctions in the cable also reflect RF currents, which go back to the source. It is impossible for the signal power to reach its final destination because of these reflections. Transmission lines are constructed with particular impedance matching and specialized construction in order to minimize electromagnetic signal reflections and losses. The characteristic impedance of most transmission lines is that they have a consistent cross-sectional size over their length, which prevents reflections. If a cable or media has a high enough frequency, the wavelength of electromagnetic waves travelling through it will be shorter than normal. Short wavelengths need transmission lines, since the cable length becomes a substantial component of the wavelength. To reduce power losses, waveguides are utilized instead of transmission lines at microwave frequencies and higher, which act as "pipes" to contain and direct waves. Optical technologies like lenses and mirrors are used to steer electromagnetic waves at even higher frequencies, such as the terahertz, infrared and visible ranges.

SERIES COMPENSATION IMPACT ON TRANSMISSION LINE PROTECTION

The protection becomes more complicated when series compensation is included into the transmission line. Because of this, the apparent impedance that is detected by the relays is going to shift. The measurements of voltages and currents that have just been completed are used by the distance relay to resolve the impedance calculations. The inclusion of the series compensation causes the impedance calculation to be inaccurate,

The comparison of these two data makes this argument quite evident (b). As a result of including series compensation in the design, the characteristic underwent a change at the point of compensation, as seen by the solid lines in Figure 1(a) and 1(b) (b). This shift in the characteristic can be shown to have taken place ever since the compensation was included in the series (b). When looking at Figure 1(b), it is easy to see that the distance relay would experience an overflow in the event that a Series Capacitor (SC) was added to the fault circuit. In the event that a defect presents itself immediately after the compensator for end line compensation, as seen in Figure 2, the ability of the distance relay to maintain its directional integrity is put in jeopardy. This is because the compensator for end line compensation is located immediately after the defect.

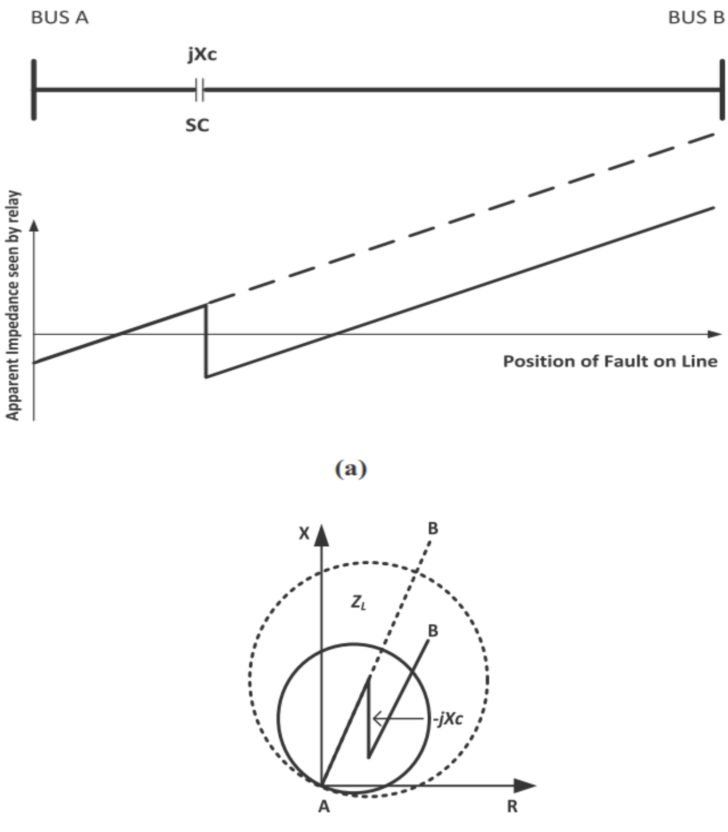

Figure 1: Change in impedance as seen from relay

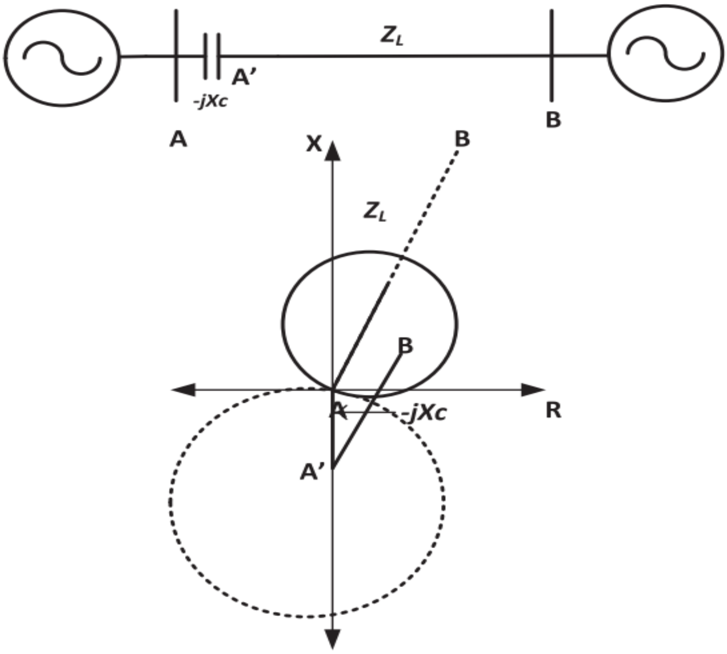

Figure 2: Loss of directional integrity in case of end line compensation

OVER VOLTAGE PROTECTION OF SERIES CAPACITOR

This is because it is only then that it is necessary to accommodate the series compensation. On the other hand, the overvoltage protection of the series capacitor may be able to remove the capacitor from the faulty circuit. A Spark Gap (SG), a Metal Oxide Varistor (MOV), or both, together with a bypass circuit breaker, is the standard method for protecting a capacitor from an excessive amount of voltage. This method is shown in Figure 3. Because of this, there are two distinct impedance states that occur during a fault:

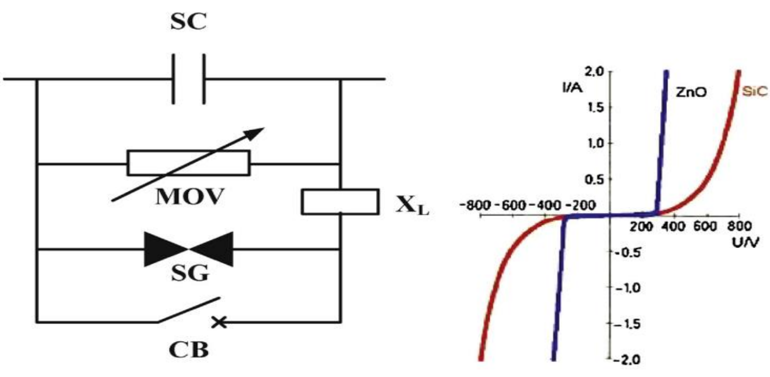

Figure 3: Over voltage protection of series compensator and MOV characteristic

1. If there is a fault situation that involves a high current, the voltage across the capacitor will rise to an extremely high value, which will cause the MOV to conduct and bypass the

capacitor. In this scenario, the impedance of the SC–MOV combination will be lowered to the impedance of the MOV by itself.

2. Even though there was only a little amount of current flowing through the fault, The impedance provided by the SC–MOV combination is equivalent to that provided by the parallel combination of the pair.

There are two different impedance circumstances that make relay configuration more challenging. Without taking into account the MOV conduction, the placement of a relay runs the risk of overreaching and quickly losing its directional integrity. It is possible for the relay to underreach under low fault situations if the parameters are changed while continuing to take MOV into persistent account.

APPLICATIONS OF THE SVC SYSTEMS IN TRANSMISSION SYSTEMS

- Aims to improve efficiency and transient stability of active power transfer
- In order to effectively manage the voltage
- To reduce power sags

By adding an SVC to your network, you'll be able to transfer files more quickly and have fewer dropouts. As an added benefit, voltage amplitude modulation in an SVC may help reduce active power oscillations. SVC installations are made up of a variety of components. The thyristor valve is the most critical component. SVC topologies with TCR/TSC/FC or TCR/FC are the most frequent. Utilizing these branches has the primary benefit of decreasing losses. Mechanical switched banks are included on both the LV and HV sides of the SVC transformer to boost the overall reactive power support. Two parallel reverse connected thyristors are used to regulate the shunt linked reactor in both TSR and TCR. A step change in reactance occurs as a consequence of controlling TSR with no regard to firing angle. In a continuous operation, TCR is regulated by the firing angle input. TSC's way of operation is quite similar to that of TSR. The capacitor's characteristic allows the reactance to be completely detached or completely connected, depending on how it is used. An SVC may provide or absorb reactive power from or to the transmission line using various combinations of TSC and fixed capacitors, TSR/TCR.

2. LITERATURE REVIEW

Rahmani-Andebili, M. (2022), The transmission line model and performance issues are discussed in detail in this chapter. Transmission line models, transmission line voltage control, transmission line compensation, and transmission matrix characteristics are among the topics covered. There are three degrees of difficulty in this chapter: easy, normal, and hard, and the calculating amounts for each issue are divided into three categories (small, normal, and large). In addition, the tasks are arranged from the simplest to the most challenging, based on the number of computations required.

Zheng, T.etal (2022), Reclosing on a permanent fault would result in a second outage of the power grid in a short amount of time since the typical auto reclosing technique cannot recognise the fault characteristics when they occur at a UPFC compensated transmission line.

This work presents a fault detection system based on the active injection of the characteristic voltage by the control of the UPFC in order to tackle this challenge. When both sides of a bad line have tripped their circuit breakers, it's time to move over to extra control mode on UPFC's series converter. Series transformers are used to actively inject the line's typical voltage. The differences in characteristic voltages and currents under various faults may be used to identify fault characteristics via active injection. As a result, the circuit breaker might be kept from re-closing in the case of a persistent problem thanks to this design. PSCAD/EMTDC simulation results show that the suggested approach is both reliable and effective.

Taheri, B. etal. (2022), Since parallel lines are able to increase the transmitted power and network dependability, they are an essential element of power systems. However, because of its complexity, fault location has always been a possible issue with these transmission lines. Fault-finding algorithms will face additional difficulties if wind farms are linked to the electricity grids. This is because the impedance in wind power plants is always changing. Static Var Compensator (SVC), a compensating device for power transmission lines, may also pose issues with pinpointing the exact spot where a problem exists. This research thus proposes a novel approach for the estimate of source impedance and other network properties, which are crucial elements for the precise calculation of the fault location, based on Long Short-Term Memory (LSTM) networks. PSCAD and Python software are used to run the simulations on a two-circuit network. Wind farm, synchronous generator, and two parallel lines make up the network's power source. The DFIG model is used to represent the wind farm in the network examined. The test results show that the suggested approach may be used to accurately predict the location of the fault and the impedance of the source. The findings acquired from the testing.

Fahim, S. R. etal. (2021), The capacity of the transmission line (TL) is increased by using a series capacitor, but the voltage/current is inverted and a sub-harmonic frequency is created, causing the protective mechanisms to operate unintentionally and further reducing the transient stability under fault situations. A precise diagnosis of TL faults is required in order to restore transitory stability, and this needs deeper research of in-depth characteristics. Existing methods have difficulties since they need a lot of data. As part of this article, a weight-sharing capsule network (WSCN) that is self-attentive is developed in order to obtain robust and high classification performance while using a little quantity of data. The weight-sharing method in the capsule network provides reliable performance in identifying and categorising TL domain errors. At the same time, the self-attention layer emphasises the more prevalent traits that allow the network to successfully function with the limited amount of information. Self-attention WSCN was examined using a Western System Coordinating Council WSCC 9-bus and 3-machine test model that was fitted with a series capacitor. The suggested network's explicit categorization ability was confirmed by comparing the findings with those from other networks. Validating the suggested self-attention WSCN on real-world data from the power network was also done.

Kothari, N. H. etal. (2021), Support Vector Machine (SVM) is used to classify transmission line faults in thyristor-controlled series-compensated (TCSC) systems (SVM). It is suggested that the post-fault magnitude of Rate-of-Change of Current be used in this method (ROCC). ROCC of three-phases and zero sequence current were used as inputs to the SVM classifier for fault classification. A binary-class and multi-class classifier based on SVM was tested to see how well it performed in this application. Using PSCAD/EMTDC software, a TCSC-based 400 kV, 300 km long transmission line was simulated to assess the technique's validity. Using the aforementioned model, we were able to produce 41,220 different types of faults by altering various fault and system factors. The effects of window length, saturation of the current transformer (CT), noise signal, and sampling frequency were also investigated. The suggested method was shown to be 99.98 percent accurate in 37,620 test instances. Additionally, a 12-bus power system model comprised of a 365 kV, 60 Hz, 300 km long TCSC line showed consistent performance while analysing the recommended approach. SVM-based approach is obviously better in terms of fault classification accuracy when compared to other contemporary techniques.

Almomani, M. M., & Algharaibeh, S. F. (2020), High-voltage and extra-high-voltage AC transmission networks often use FACTS technology to regulate the flow of electricity. Using a typical distance relay is no longer possible because of the presence of FACTS devices. For any compensated transmission line, a brand-new unique pilot distance protection mechanism is provided in this study. This plan works with any FACTS device, regardless of kind (shunt, series, or compound), at any operating point (capacitive mode or inductive mode). MATLAB 2020a/Simulink is used to simulate and test the proposed system. There is a defect detection method in the model, as well as phase selection, impedance measurements, and a mho characteristic with five zones to consider. In addition to the three standard zones, there are two extra inverted zones in the proposed plan. There are a variety of situations that the model may be tested under: single-line ground, double-line ground-to-ground and three-phase ground-to-ground faults. Static synchronous compensator (STATCOM), static synchronous series compensator (SSSC), and unified power flow controller (UPFC) are examples of shunt, series, and compound FACTS devices, respectively, in terms of model robustness. A variety of FACTD device locations, fault kinds, FACTS device types, and operating points all indicate that the relay works as expected.

Ghazizadeh-Ahsaee, M. (2020), Lines may be returned to service more quickly if fault location algorithms are accurate. For series compensated transmission lines, the kind of fault and/or the model of the compensator must be known prior to fault site estimation in the previously reported techniques. As a result, their precision is closely tied to the approach used to classify fault types and/or the compensator model itself. Transmission lines compensated by series devices may be located by synchronising instantaneous data from both ends of the line and using the distributed parameter line model in the time domain to locate faults without needing a specific kind of fault. First and foremost, it not only identifies the problematic phases, but it also estimates their locations concurrently; secondly, it is independent of the type of the series devices, thus it is applicable to transmission lines compensated by any series compensator. This research investigates the novel algorithm's performance in a broad range of fault scenarios, including those using a TCSC and a Static Synchronous Series Compensator (SSC) (SSSC). Fault type classification and location accuracy are high, according to the findings of the experimentation.

Chernet, S., etal. (2019), DFIG-based wind farms linked to series-compensated transmission lines are the focus of this paper's investigation of the possibility of subsynchronous control interaction (SSCI). The frequency-dependent input admittance of the DFIG is modelled in detail for this purpose. The DFIG wind turbine generating unit's frequency characteristics may then be deduced using the admittance model that was established. Power dissipation features of DFIG are used to identify control factors and operating conditions that have the greatest influence on the behaviour of wind turbines in subsynchronous frequency band. With the use of a series-compensated transmission line's impedance model, SSCI risk may be determined for a wind farm. When the rotor current controller's closed-loop bandwidth is reduced, the system's stability suffers. This may be shown using the Generalized Nyquist Criterion. Results also demonstrate that the degree of series compensation and the active power set-point have an essential effect in the overall system's stability. The theoretical conclusions are tested using time-domain simulations.

Karunanayake, C. etal. (2019) Wind turbines with doubly fed induction generators (DFIG) and series compensated transmission systems may reduce sub-synchronous resonance (SSR) using a nonlinear sliding mode control (SMC). The rotor side converter is controlled using the suggested way to reduce SSR while maintaining the DFIG's decoupled torque and reactive power management capability. The suggested technique is validated by simulations using a comprehensive DFIG wind turbine model from the RTDS platform. The controller was shown to be effective in damping SSR when tested at varied compensation levels and wind speeds.

Sharma, N., etal. (2018) The Hilbert-huang transform is used to detect and identify problematic phases in a three-phase series capacitor-compensated transmission line linked to a wind energy source. Single-ended fault current data is used in the suggested method. On the proposed design, tests have been run for a wide variety of faults, each of which has its own distinct set of fault characteristics. These characteristics include the type of fault, the location of the fault, the fault resistance, the fault onset time, and the ground resistance. Additionally, the ground resistance has been tested. The findings of the testing indicate that the approach that was recommended is reliable and advantageous.

Patel, B. (2018), Digital relaying is presented in this study for the detection, classification and localization of faults on the hybrid transmission lines consisting of an overhead line and a cable that is buried below. Faults may be predicted by using the entropy principle and fast discrete orthogonal S-transform (FDOST) represented by window-dependent bases for feature extraction and the support vector machine (SVM) classifier model and support vector regression (SVR) model for pattern recognition. For each of the three current signals, the entropy of FDOST coefficients is extracted from half-cycle duration following the onset of the fault in order to model and simulate the transmission system in the Electromagnetic Transient Program programme. It has been tested on a single-junction and a multi-junction hybrid transmission lines under various fault situations and proven to be quick and accurate regardless of the fault type, fault section, the fault resistance, the fault inception angle (FIA) and the load angle. Furthermore, the suggested approach is tested for noise immunity by using fault current signals impregnated with 30 dB white Gaussian noise (SNR).

Gajare, S., etal. (2017) Analytical and dynamic simulations and relay configurations need proper model parameters of many aspects to provide exact results. Due to weather and age, it is required to verify transmission line parameters at intervals. Methods to estimate the parameters of series-compensated lines utilising synchronised time-domain data acquired by intelligent electronic devices at both ends of the line are presented in this study that are free of the compensation model. Disruption generates waves that propagate down a line, which are used to calculate its propagation constant, which is used to determine its resistance and impedance. Finally, the line's inductance and capacitance are determined.

Liu, H., etal. (2017), Subsynchronous resonance (SSR) has recently emerged as a concern in series-compensated wind farm systems. It was decided to focus on the features of this problem using only simpler single-machine, infinite-bus systems in the prior study. The influence on SSR of several essential parameters, including as the topology of the network, the distribution of wind farms, the variety of wind turbine generators and the dispersed wind speed, cannot be reflected as a result.. This research presents an SSR stability analysis approach based on an impedance network model (INM) to close the hole. Each wind farm and transmission line has its own impedance model, which is then linked together using a system architecture to construct the INM as a whole. A lumped impedance is formed as a result of such INMs. A novel stability criteria for SSR is created by examining the impedance-frequency properties of the latter. Using a real-world power system with many wind farms, the criteria may be used. The usefulness and precision of the system have been shown by both field measurements and time-domain simulations. Analyzing the SSR problem for extremely large-scale wind generating plants may be greatly aided by the technique presented here.

Zhang, etal. (2016), The distributed parameter line model is used to develop a novel two-terminal fault-location technique for series-compensated double-circuit transmission lines. The series compensator has two subroutines, one for the left and one for the right side of the series compensator. Because the sequence voltages estimated from two sides are equivalent at the fault site, the voltage of a series-compensated device is deleted in each subroutine. Fault locator functions are designed to take use of the property that the transition resistance is completely non-resistive at the area of the malfunction. This method does not need that the kind of fault be known, and there are no issues with finding the location of the fault and eliminating the pseudoroot. The excellent accuracy of the proposed fault-location approach is confirmed in MATLAB by using PSCAD to create multiple fault instances under various situations.

Liu, Y., etal. (2016), When it comes to protecting transmission lines, series compensated lines pose a new threat. To deal with these issues, an EBP approach based on dynamic state estimation is presented in this study. An analysis of the dynamic model of the protective zone and how it affects the effectiveness of the protection system is presented in this research.. The approach can accurately detect defects, regardless of their location or nature, according to numerical simulations. Distance protection and line differential protection, both of which have been used in the past, are contrasted with the new technique suggested in the study. Faster fault detection, immunity to current inversion produced by series capacitors (SCs), and enhanced detection sensitivity for high-impedance faults were found in the comparison between the two systems.

Çapar, A., & Arsoy, A. B. (2015), New fault-finding algorithms are proposed in this study for transmission lines that have been compensated. If the fault occurred before or after the compensator position on the line, that fact is taken into account while doing the fault location calculations. Determine if the fault is in front of a compensator by using an estimated MOV impedance. Many different kinds of faults, as well as fault locations and fault resistance, were tested on a 380 kV transmission line using a series capacitor and MOV. The findings reveal that the algorithm correctly predicts the location of the defect in every situation.

Adrees, A., & Milanović, J. V. (2015), The paper's approach is based on a thorough risk assessment of SSR, which takes into account the severity of subsynchronous resonance and the likelihood that it will happen. The severity of subsynchronous resonance is assessed using the risk score defined before. The line outage model is used to estimate the likelihood of subsynchronous resonance in the event of an outage. Even with the most basic control, it has been shown that the risk of SSR can be effectively handled with a relatively little involvement of TCSC.

3. MODELING FOR TRANSMISSION LINE

A transmission line can be represented as a two-port circuit using ABCD parameters which determine the relationship between voltage and currents in sending and receiving ends. The accurate representation of an actual transmission line may be done only in terms of uniformly distributed parameters r (series resistance), l (series inductance), and c (shunt capacitance). For short lines (less than 80 km) and medium lines (between Power flow or load flow in an ac power system deals with the calculation of bus voltages and their phase angles as well as the flow of active and reactive power through various network elements under steady-state conditions. This provides a systematic mathematical approach, which is an essential source of engineering information for planning, design, and operation, as well as an important tool for several other fields of power system analysis such as stability, symmetrical and asymmetrical faults, and system harmonic studies.

In power systems, generators are usually treat Up to now, we have studied the power system under normal operating conditions. Any failure in a power system which causes short circuit of a section is called a fault. This short circuit creates a low-impedance path through which fault currents greater than normal condition can flow. As these fault current magnitudes can be several times larger than normal, they may cause damage to the power system equipment. These damages could be categorized as electrical and mechanical. From the electrical view point, excessive current flow may cause thermal damage to solid insulation or metallurgical damage to conduct An unsymmetrical or asymmetrical fault is defined as a fault that affects one or two phases of a three-phase system in contrast with the previously studied balanced or symmetrical faults which equally affect each of the three phases.

Unsymmetrical faults constitute more than 95 percent of all faults occurring on a transmission line. Although this type of fault involves lower fault current magnitude than symmetrical faults, its study is particularly important with regard to system stability considerations, relay setting, and single-phase switching. As well, current flow into the ground from unsymmetrical faults can affect Control of voltage and power flow is one of the essential and important tasks in power system management, particularly for modern power systems with a large number of components and interconnections for ensuring power quality and reducing losses.

In addition to maintaining voltage at all buses within an admissible range and to increasing transmission line power transfer, control of voltage and power flow aims at improving the system stability and economic operation. There is a strong dependency between active power flow (P) and voltage angle (δ) on the one hand, and reactive from engineering viewpoint stability is the ability of a system to return to its steady-state condition after being subjected to a disturbance. Stability for a synchronous machine in a power network refers to recovering its synchronous speed after having been subjected to a disturbance due to changes in the input or output power. Power system stability refers to maintaining the synchronism between the various parts of a power system. Stability considerations are recognized as major concerns in power system planning and studies.

SIMULATION PARAMETER

Three-Phase Source

Rms voltage - 250e3

Frequency – 50Hz

Three-Phase Series RLC Branch

Resistance 6

Inductance – 0.053H

Three phase Load

Active power -304.8e6

Inductive power - 228.6e6

SIMULATION LAYOUT

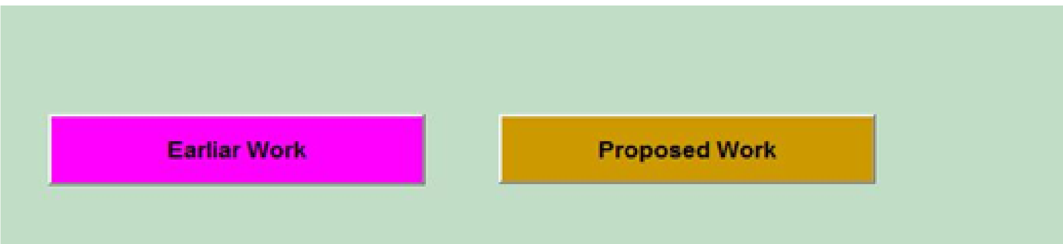

Figure 4: Basic layout designed in MATLAB 2013a that contains two button Earlier is for perturbation theory and proposed is for modeling of transmission line

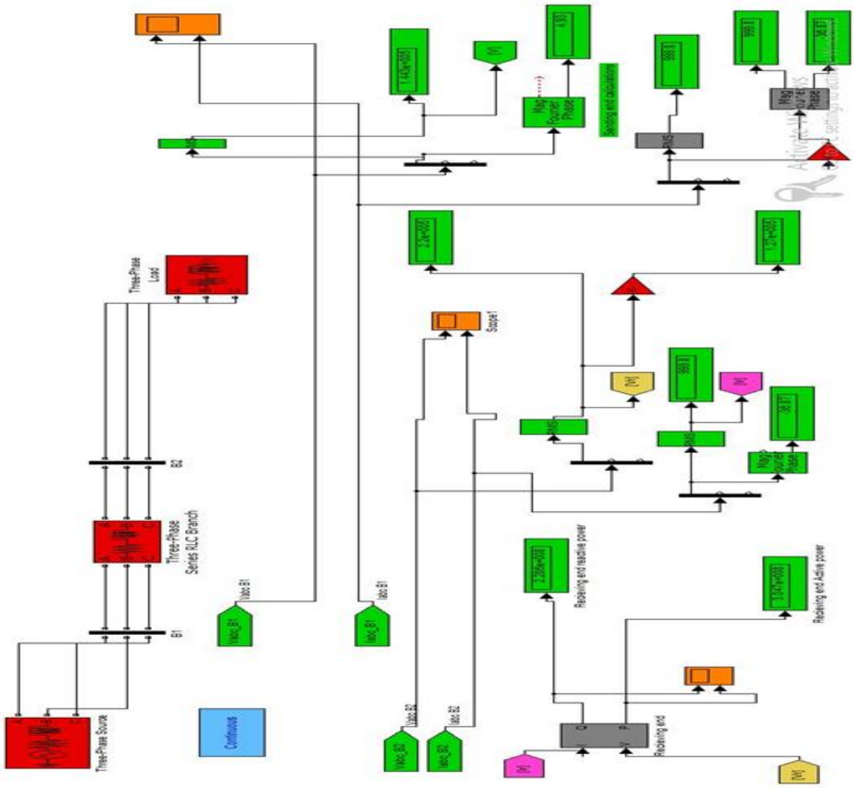

Figure 5: Simulation of Transmission line using MATLAB

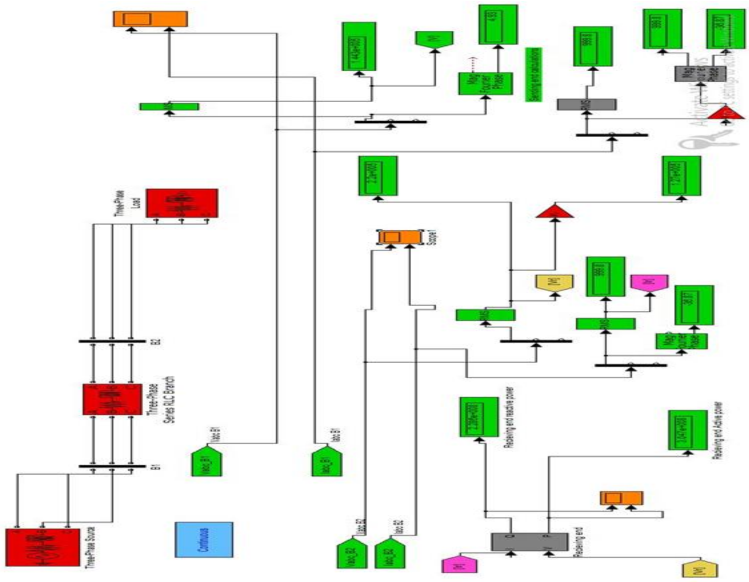

Figure 6: Simulation in running time (Green Box shows the timer) for transmission behavior

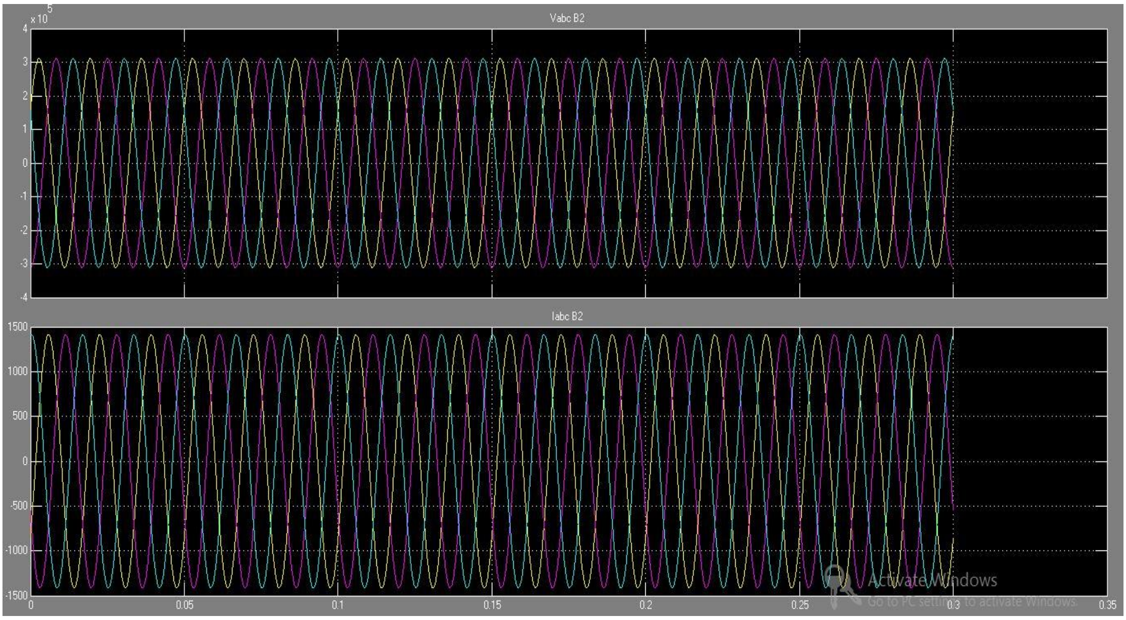

Figure 7: Output of scope 1(Sending End of transmission Line)

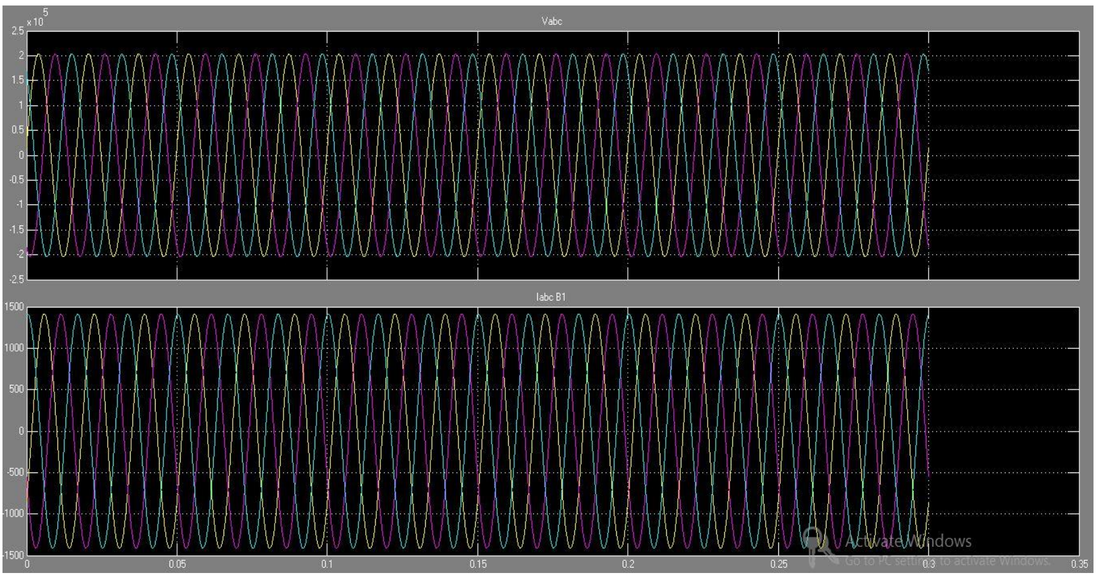

Figure 8: Output of scope 2(Sending End of transmission Line_on sends the Different parameter of voltage and current)

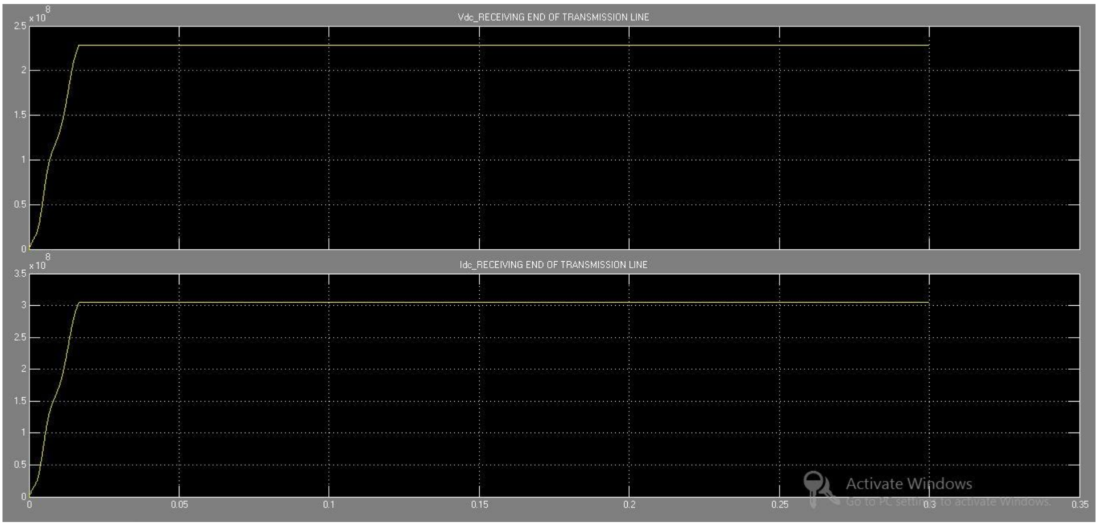

Figure 9: Output of scope 3 (Receiving End of transmission Line)

The simulated output find in the three different scopes that is in MDL file of simulink. One is on the side of sending end, second find the same end but with different parameter of inputs and the last one is on the receiving end of transmission line.

4. CONCLUSION

In this paper the technique that has been developed for the analysis of a transmission line in which the distributed line parameters per unit length are non-constant. In this paper we consider the transmission line having the inhomogeneous distributed parameters. And the transmission line is infinitesimal line. Here is a method for the analysis of non-uniform transmission line by using the perturbation method. The starting point for the method is the KCL and KVL of the line for the infinitesimal line length. These lead to force a system of the coupled first order linear differential equations for the voltage and current along the line. These differential equations have non constant coefficient in view of the in homogeneity of the line. For implementation of perturbation theoretical method, we start with the original system of coupled differential equations is expended in state variables from with the state vector being the voltage and current variables along the line and deriving 2×2 matrix being built out of the distributed parameters. This matrix is decomposed into the sum of a constant 2×2 matrix and a varying 2×2 of the parameters; we arrive at a sequence of linear differential equations for each order. Matrix assumed to have small norm which guarantees the applicability of the perturbation theory. In Modeling file it is been created a short transmission line which has parameter as discussed above. It has clearly shows that the output graph of frequency becomes linear just after the simulation starts. It has clear that the transmission line has stable output and very less distortion.

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