IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

IJARSCT
Impact Factor: 6.252

Volume 2, Issue 7, May 2022

Generation of Power Quality Events of Different Underlying Causes using Simulation

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Abstract: *The modern power system is plagued by many PQ disturbances that demand proper addressing. Many underlying causes lead to occurrence of PQ disturbances. Hence, it is necessary to analyze the root cause of the disturbance in Power Quality to facilitate corrective mitigation. This paper presents ways of generating power quality disturbances of different underlying causes using MATLAB simulation model. The voltage sag is the most commonly occurring PQ disturbance in power system. The various voltage sags are generated due different underlying cause like large transformer energization, Induction motor starting and line fault. The symmetrical and unsymmetrical voltage sags are generated using line fault Simulink model. The system is presented for the development of oscillatory voltage transients caused by capacitor bank energization. The first step for the aforementioned analysis is to generate required PQ disturbances. As a result, these models are applied to the development of power quality analysis algorithms to mimic various underlying reasons for power quality waveforms.*

Keywords: Voltage Sag, Oscillatory Transient, MATLAB Simulink

I. Introduction

Power system engineering includes a branch called power quality. It is crucial in ensuring the quality of power given to the customers [1-2]. The liberalization, privatization of the power system network and addition of non-conventional sources of energy along with dispersed generation interfere with the power system thus contributing to the significant increase in the amount of operations in the PQ sector [3]. This leads to occurrence of the different underlying reasons for PQ disturbances. The nonlinear nature of industrial loads, viz transformers, variable speed drives, solar inverters, and power supplies, among others, has led to disturbances in power quality in electrical systems [4]. PQ issues in electricity delivery result in financial losses. They have the potential to harm or cause erroneous operation of both grid and end-user equipment [5]. They can cause loss of data and storage failure in loads like computers, protection, PLC's, and relay equipment, as well as irregular behavior of electronic controls in end-user systems [6]-[7]. As a result if identification, classification, and mitigation of such issues isn't done properly, it might result in the failure or malfunction of a large number of such loads, that are sensitive in nature, linked to the system, that can exact substantial costs. Transmission networks are also affected by PQ disruptions. This is especially true in power systems that use sustainable energy sources like photovoltaic generating, which necessitates the use of non-linear electronics. Thus, detecting and classifying PQ disturbances is essential before integrating sustainable sources of energy in main grid, or identifying cause of disturbance and taking mitigating activities in industry networks [6]. Obtaining numerous deform waveform to test the systems is the 1st stage in study based on automatic detection and categorization of PQD. Many tendencies emerge from existing research in this regard: Wave generation using mathematical models [7]-[10]. In [3] the distribution system is simulated for the generation of PQ disturbances for identification of different underlying reasons.

II. SIMULINK MODELS

The document describes Simulink models such as transmission line failure, induction motor starting, transformer energizi ng models. The model's distribution voltage level is based of Grid code for Malaysia.

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Line Fault Model:

Figure depicts the Simulink-created line fault model. The line fault model is utilized for mimicking voltage dip produced by aforementioned fault. The given model comprises of a 3-Φ 11kV 50Hz source block supplying 500kVA resistive inductive load through an 11kV/415V 1MVA pi/t transformer.

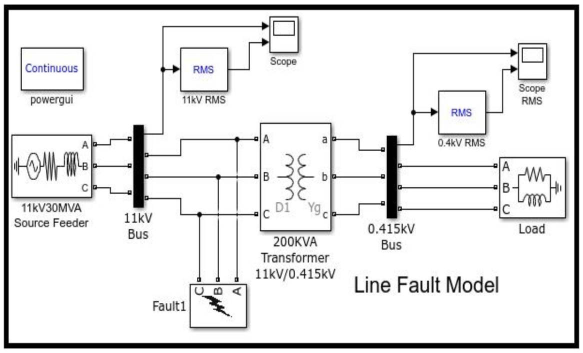
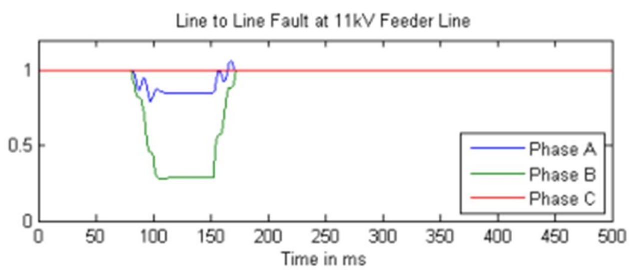
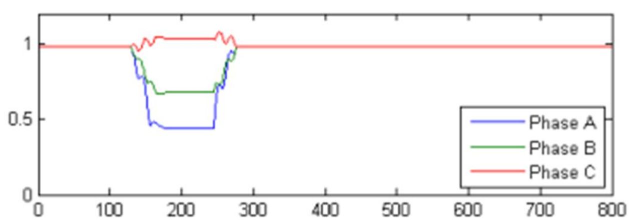


Figure: Line fault model for simulation

A fault block is positioned at the source feeder line and simulates many types of line faults, as well as a multistage fault block. This model is able of simulating single line to ground, double line to ground, line to line, 3 Φ, and multistage faults, among others.

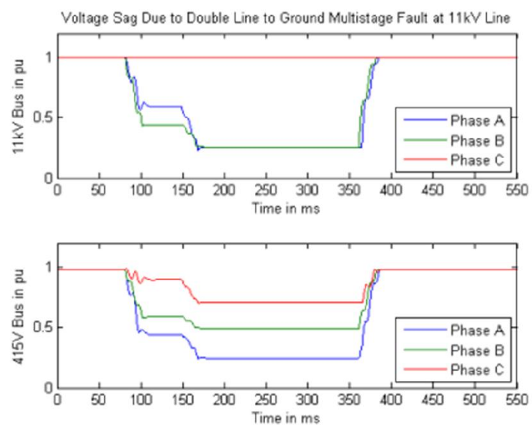
To find the voltage sag and swell by using this model. The voltage dip travels from the transformer to the load, and the fault type is determined by the transformer's delta and star arrangement. The high fault resistance or weak source causes the voltage surge during the unfaulted phase.





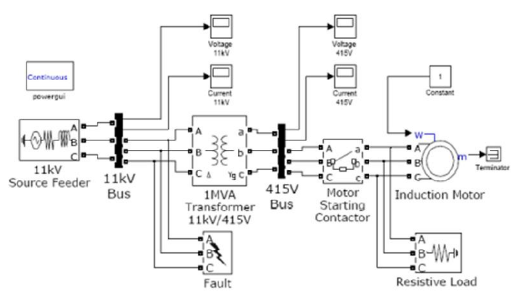
The given model is also capable of simulating multistage line faults.

Synchronisation issue of numerous fault cleaning algorithms causes the multistage voltage sag [16]. This causes transient changes in power system impedance and network topology, resulting in numerous phases of voltage sag before returning t o its nominal level. Various types of faults happening within a small period of time and recorded as a single occurrence are referred to as multistage voltage sag. Figure 3 depicts a multistage voltage sag in RMS caused by a double line to ground fault with a fault resistance variation from 0.2 to 0.1 ohms, with ground resistance ranging from 0.1 to 0.01 ohms. Fault on an 1100 V feeder line that is spreading downstream 415V bus.

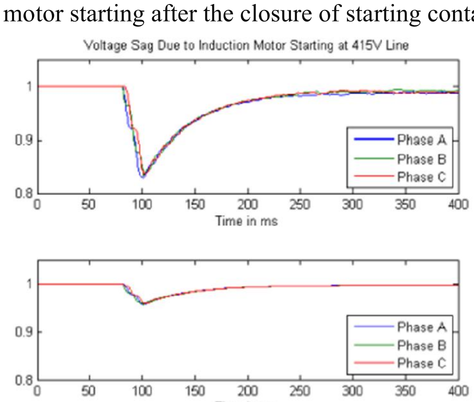


Model of an Induction Motor Starting

Voltage sag with features caused by normal induction motor beginning is simulated using the Simulink model. The starting model for induction motors and Simulink's load model for an induction motor is as depicted in Figure 4. The voltage sag caused by an induction motor starting may be simulated by the starting model for an induction motor; voltage sag is influenced by the load on the induction machine as well as a multi-stage failure. An 11kV 50Hz transformer is used in the model. To approximate a typical combination of industry load, a 3 **Φ** source feeder block feeding through 1100V/415V pi/t transformers, a motor starting contactor, a 3 **Φ** induction motor, and a 1000 W resistive load were used. At 1100 V and 0.415KV buses, there are instantaneous voltage and current scopes.

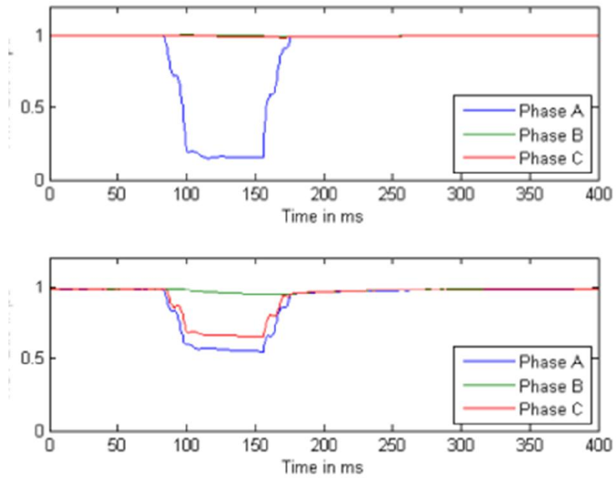


Two fault blocks, one at either end of the 11kV feeder line, are utilized for simulating line fault caused by induction motor loads. This model simulates voltage dip generated by starting an induction motor load. Figure 5 depicts a 3 **Φ** voltage dip generated by a 150 HP induction motor starting after the closure of starting contactor of motor.



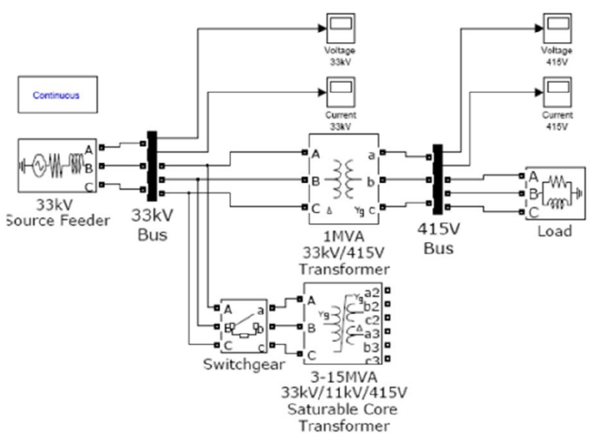
The voltage drop on the 0.415KV bus travels upwards to the 1100V feeder bus via transformer. The amplitude of the voltage sag goes on increasing as it moves upwards to the 11kV feeder, finally becoming inconsequential. The magnitude of the voltage sag in an induction motor is dictated by the induction motor's power rating. The lower the sag, the higher the induction motor power rating dictated by the induction motor's power rating the lower the sag, the higher the induction motor power rating magnitude.

The induction motor starting model can also be used with an induction motor load to simulate voltage dip induced by a line fault. The voltage dip generated by a single line to ground fault on an 11kV feeder line is shown in Fig. 6. The usual rectangular voltage sag pattern is modified by the induction motor's activity as the voltage sag propagates downstream toward the 415V bus with induction motor load

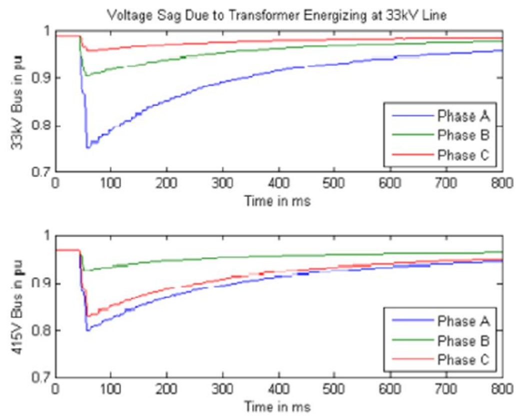


Transformer Energizing Model (Model C)

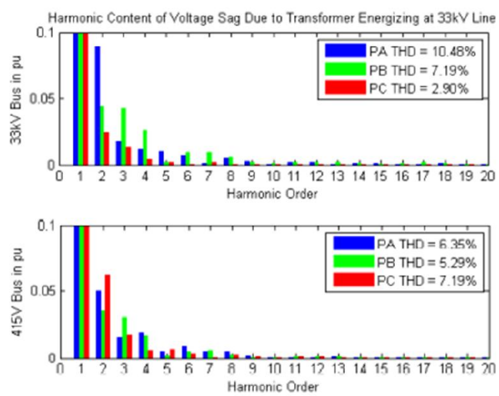
Simulink's transformer energising model is as follows: as seen in Fig. It's used to simulate voltage dip induced by various factors. During the large current and core saturation of the transformer invigorating. The model is a 3-Φ 33kV 50Hz system. A 3MVA saturable core transformer receives power from a source block switchgear as a barrier. The 33kV feeder bus also supplies power to power to a 500kVA transformer through a 1MVA 33kV/415V transformer inductive resistive load This model allows you to simulate voltage drop due to transformer energization.



After the switchgear that that provides the power to the transformer is closed, Figure 8 shows the voltage drop induced by the transformer energising. Voltage sag occurs in all 3-phases, but the magnitude varies. As the voltage dip propagates downstream through the pi/t transformers, the amplitude of each Φ varies, affecting the fault class. The magnitude of the transformer power rating is determined byenergising voltage sag. When the sag voltage is smaller than transformers rating is higher.



The uniform harmonic content of voltage dip give rise by transformer energising is another distinguishing feature. The presence of high (2nd, 4th, and 6th) order even harmonics, as seen in Fig. 9, is a unique property of voltage dip give rise by transformer energising.



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