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Power Supply For Electric Traction Drives

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Abstract

For more than a decade, the railway has experienced a renaissance in many countries after several years of decay. The main reasons for the renewed interest in the railway are environmental, economical, and safety related. This has quite naturally, in turn, increased the interest in railway associated research. Both passenger and freight transports on railway are increasing. In order to cope with this increase, large railway infrastructure investments are expected. An important part of this infrastructure is the railway power supply system – without it, only the weaker and less energy efficient steam and diesel locomotives could be used. The power demand depends upon the train speed that in turn is related to a number of factors categorized by system specifications and operation conditions. The former includes traction equipment characteristics, track layout, signaling and speed restrictions whilst the latter covers the positions of trains, headway, traffic pattern and drivers" behavior. As if it were not complicated enough, a train might become a generator should regenerative braking be possible. As a result, the study of traction power supply system becomes the major focus for many researchers recently.

KEYWORDS:Power, Traction, Power traction, Catenary and Railways

1. INTRODUCTION

The research work provides an introduction to railway power supply systems in general, and also defines the aim and the objectives. For more than a decade, the railway has experienced a renaissance in many countries after several years of decay. The main reasons for the renewed interest in the railway are environmental, economical, and safety related. This has quite naturally, in turn, increased the interest in railway associated research. Both passenger and freight transports on railway are increasing. This is not an increase only in the number of departures, but also heavier trains for goods, and faster trains for personal transports. In order to cope with this increase, large railway infrastructure investments are expected. An important part of this infrastructure is the railway power supply system – without it, only the weaker and less energy efficient, WOLFGANG L.(2010) steam and diesel locomotives could be used. Due to massive advantages of electric power supply compare to diesel fuel, there has been a gigantic acceleration in railway traction development in Ethiopia and other parts of the world.

1.1 Statement of Problem

The transportation demand in Nigeria is increasing as a product of economic development and population growth. The cost of petrol for fueling the locomotive drive is very alarming and any other means that uses such as start and stop drive. To cop up with this demand, the Nigeria government have to implement a rail transport system in two phases. In the first phase the country is to construct Light Rail Transit (LRT) in the capital city, Abuja and freight and passenger train transport from Abuja to Lagos, Rivers etc. In the second phase construction of a rail transport system that joins the main cities of the country including rail line connection with neighboring country will take place.

1.2 Significance of the Study

The electric traction system is the most efficient of all other traction system Kale et al., (2014) such as steam and internal combustion (IC) engine type systems. It offers several benefits over other systems, including quick start and stop, very efficient, pollution-free, easy to handle and easy speed control.

2. MATERIALS AND METHODS

2.1 Materials

The knowledge of railway and steam engines has been around since the sixteenth century. Wagon roads for coalmines using heavy planks were first designed and built in 1633 (L. WOLFGANG 2002) Mathew Murray of Leeds in England invented a steam locomotive that could run on timber rails in 1804 and this was probably the first railway engine C. Courtois (2012).

Although railway and locomotive technologies were continually developed, the first electrified railway was introduced in the 1880s C. Courtois; R. J. Hill, I. H. Cevik (2015). As a result of this revolution, motors and the traction power supply system have become important parts of modern electrified railways.

Apart from traction motors, traction power supply systems are physically huge electrical circuits which generally consists of traction substation, the catenary system,and other electrical system A. Mariscotti, P.Pozzobon, and M. Vanti (2010).

2.2. Traction substation

In general substations serve as sources of energy supply for the local areas of distribution in which they are located. Their main functions are to receive energy transmitted at high voltage from the generating stations, reduce the voltage to a value appropriate for local use, and provide facilities for switching. Substations have some additional functions. They provide points where safety devices may be installed to disconnect circuits or equipment in the event of trouble. Voltage on the outgoing distribution feeders can be regulated at a substation. A substation is a convenient place to make measurements to check the operation of various parts of the system. Street lighting equipment as well as on-and-off controls for street lights can be installed in a substation though this is a diminishing function. Some substations are simply switching stations where different connections can be made between various transmission lines. Whereas some are used only for specific purposes such as powering locomotives which is called traction power substation.

A traction power substation is an electrical substation that converts electric power from the form provided by the electrical power industry for public utility service to an appropriate voltage, current type and frequency to supply railways, trams (streetcars) or trolleybuses with traction current. In a substation many electrical components work together to carry out its functions, these include Lightningarresters, Switches, Distribution Bus, Circuit Breakers, Current Transformers, Isolators, Conductor systems, Insulation, Overhead line terminations, Bushings and Power transformers.

2.2.1 Traction power Transformers

The high voltage utility power is transformed to the distribution voltage by the traction power transformers. Normally, each substation is equipped with two equally-sized transformers, each transformer should be rated to be capable of handling the entire substation load and to allow for continuous system feeding in the event of outage of one of the utility feeders, transformer, or other item of high voltage equipment [R. J. Hill, I. H. Cevik (2012). The single-phase traction power transformer primary windings are connected to two of the three phases of the utility power system. Because power is being drawn from only two phases of a three-phase system, a certain amount of current and voltage unbalance will occur. Therefore, in an interconnected power utility network, the unbalanced currents and voltages will tend to balance out by the time they reach the utility generators or consumer motors J. D. Glover, M. S. Sarma, T. J. Overbye (2014).

2.3 Catenary

Electrical power will be supplied to the trains from wayside traction power substations through the catenary, which distributes the power to the train pantographs. The pantographs, mounted on the roof of the rolling stock, collect the electrical power from the catenary through mechanical contact by running or sliding under the contact wire. There are three main types of technologies used for catenaries where return currents are supposed to flow in overhead power lines instead of in the rail or through the ground. These are direct feeding with return conductor (DR), Auto

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Transformer (AT) and Booster Transformer (BT)

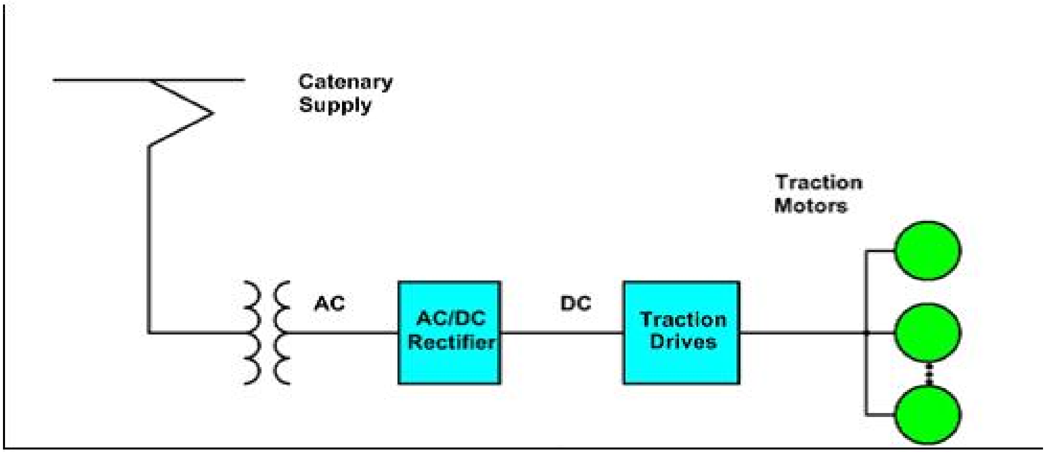

Fig.1 : The Catenary

The introduction of Booster Transformers (BT) in some countries catenary systems was necessary as a result of the high ground resistances. A high ground resistance complicates the return conduction through rail and ground F. Kiessling, R. Piff, A. Schmieder, and E. Scheneider, (2009). The complications are primarily disturbances on phone and signal systems, caused by ground currents and magnetic fields R.W. Sturland, 2014). The normal distance between BT transformers is around 15km, and between these, there is a connection between the return conductor and the rail. The purpose of the BTs is to draw the current from the return rail to an overhead return conductor. One rail is conducting, and is called "S-rail", whereas the other rail is used for signaling and is called "I-rail"

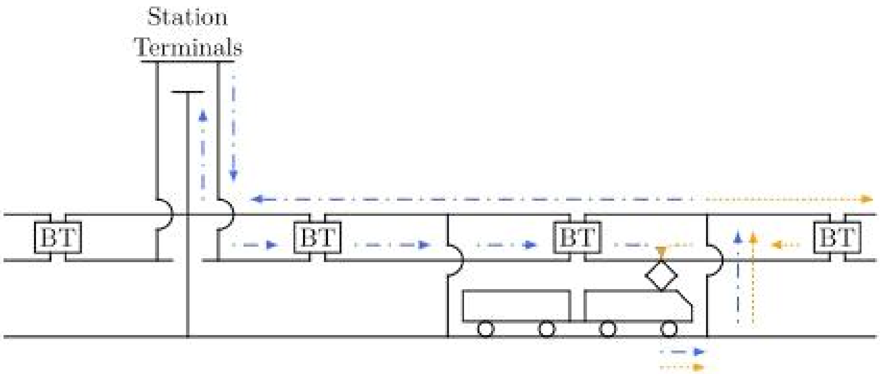

Fig 2 : An illustration of a typical BT catenary system

AT transformers are normally distributed with 10 km in between. Having allowed power to be transmitted at the voltage twice as high as the operating voltage, AT feeding improves system efficiency.

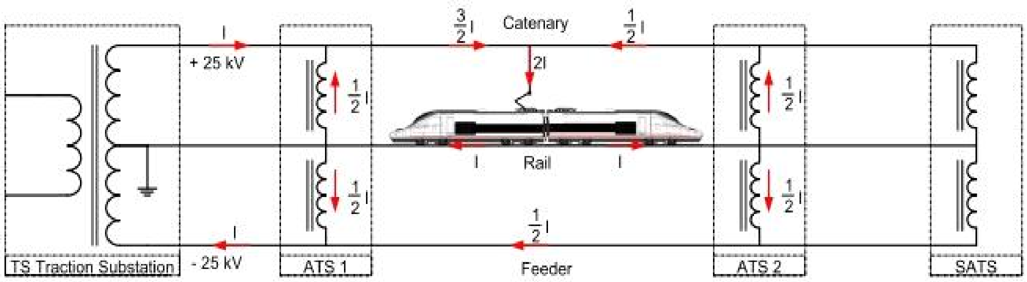

Fig 3: AT transformers are normally distributed with 10 km in between

The power demand depends upon the train speed that in turn is related to a number of factors categorized by system specifications and operation conditions. The former includes traction equipment characteristics, track layout, signaling and speed restrictions whilst the latter covers the positions of trains, headway, traffic pattern and drivers" behavior. As a result, the study of traction power supply system becomes the major focus for many researchers recently.

2.3.1 Overhead Line (Catenary)

The mechanics of power supply wiring is not as simple as it looks (diagram, left). Hanging a wire over the track, providing it with current and running trains under it is not that easy if it is to do the job properly and last long enough to justify the expense of installing it. The wire must be able to carry the current (several thousand amps), remain in line with the route, withstand wind (in Hong Kong) typhoon winds can reach 200 km/h), extreme cold and heat and other hostile weather conditions.

2.4 Comparison method

In this research works on the method used in comparing of power supply for electric traction drive is based on the observation or difference between the two electric traction system and traction drive (DC traction and AC single to three phase traction) used in this research work; More modern DC systems incorporate a wheel slip control which senses the beginning of a slip and automatically modulates the power in order to retain control. This allows the locomotive to operate safely at a point closer to its theoretical maximum.

2.5 Methodology

In order to achieve the main aim of the study there are various procedural tasks followed by the author. The first method towards processing the work is started with reviewing different literature where all the theoretical information regarding the design and simulation of power supply for electrical traction drive system is gathered and a comparison of previous similar research is studied. This is followed by studying and designing the major components of the traction power supply system. Once the design is completed, a model is developed using proteus environment and simulation is performed. Below are some major design.

2.6 Design principle of operation of electrical traction drive

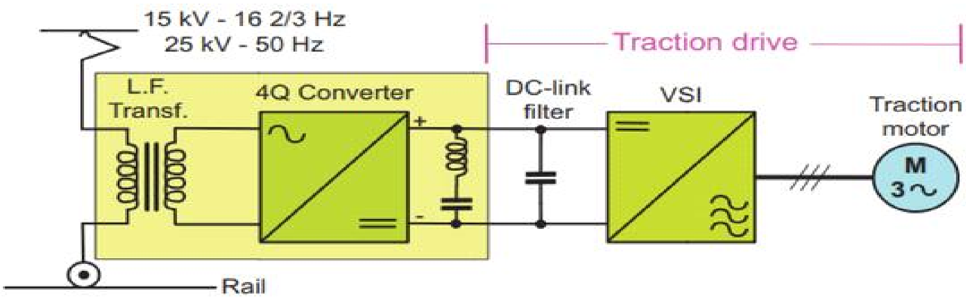

Fig 4 : The principle operation of the power supply for electrical traction system

2.7 Design algorithm of electrical traction drive

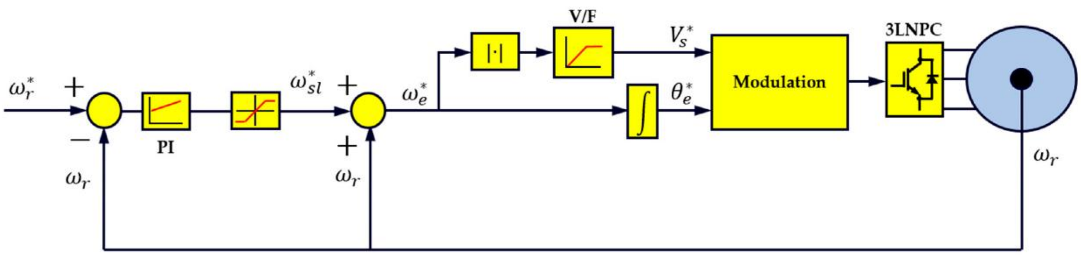

Fig 5 : Algorithm design of power supply for electric traction drive

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2.8 Design model

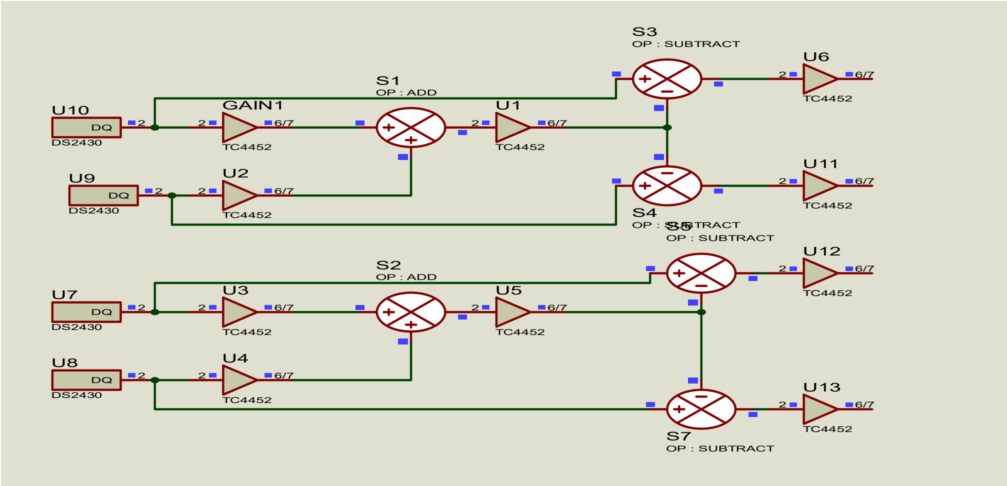

Fig 6: The model was designed and simulated with the help of protetus software

2.9 Design Implementation

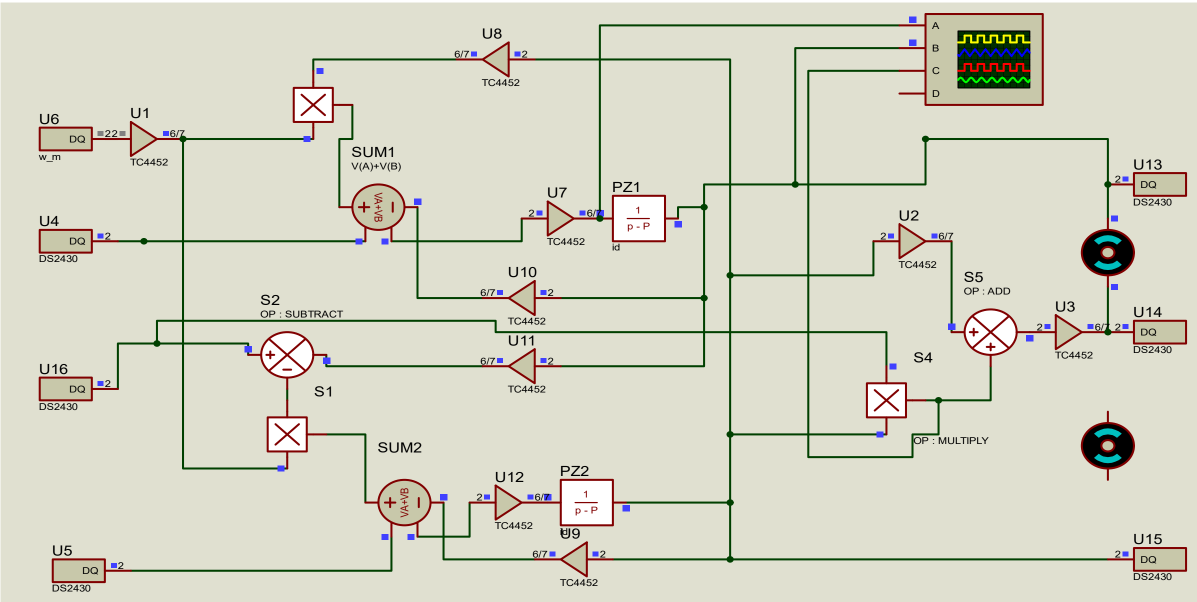

Fig 7 : The model was designed and simulated with the help of Proteus software

2.10 Simulator

Proteus was used for the simulation of the experiment, was used for extraction of some results, over the response of voltage and current, when simulated.

3. RESULS AND DISCUSSION

3.1 RESULTS

3.1.1 Result analysis

From research work on power supply for electrical traction drive there some result obtained from secondary source experiment on the research. The results are presented in table format for the following cases, followed by discussion and also graphic results are given at the end of each case and the performance of the system is investigated by applying different headway distances on the trains and by increasing the number of train along the feeding section.

Case 1: Single train

Table 1 and Table 2 show simulation result of voltages and currents respectively; also present simulation result of autotransformer (AT) voltage and current. Accordingly, discussion is made based on the results.

Table 1: Simulation Results of Voltages at various distances from the Traction Substation for single train

Number of train	Distance in km	SS output voltage	Contact line voltage	Train 1 voltage	Train 2 voltage	Train 3 voltage	% voltage regulation
One train	15	54.832 kV	27.413 kV	26.676 kV	-	-	2.68 %
	45	54.764 kV	27.380 kV	-	25.47kV	-	6.97 %
	64	54.733 kV	27.365 kV	-	-	24.778kV	9.45 %

Table 2: Simulation results of currents at various distances from the traction substation for single train

Number of train	Train position in km	SS output Current(A)			Train 1 current(A)	Train 2 current(A)	Train 3 current(A)
one train	15			593.86	587.82	0	0
		C	346.88				
		N	246.98				
	45			567.14	0	561.28	0
		C	338.85				
		N	228.29				
	64			551.85	0	0	545.99
		C	316.70				
		N	235.15				

Table 1 shows that as the train moves away from the traction substation, the output voltage of the substation almost remains the same or the substation transformer voltage drop increases very slightly as the train moves from the feeding point to the other end, for instant, the voltage drop in the traction substation transformer increased by **0.18 %** comparing results of **train 1** position (15 km) with **train 3** position (64 km), which indicates that output voltage is more or less not affected by the train position. It can also be seen that the train voltage decreased from **26.67 kV** to **24.78 kV** as the train position changed from 15 km to 64 km along the feeding section, which shows that as the train distance increases relative to the traction substation, the impedance of the traction network lifts up which in turn leads to rises in voltage drop across the catenary system.

Table 2 also indicates the train current decreases when the distance from the substation increases, this is because as the trains distance increases, small amount of current flows in different circuits such as autotransformers that does not have train in between (theoretically this current should not flow into this autotransformers but practically that is not the case because it only works for ideal autotransformers) and cause the current to return to the substation via the return conductors and it is found that the train current decreases from **587.82 A to 545.99 A** along the feeding section.

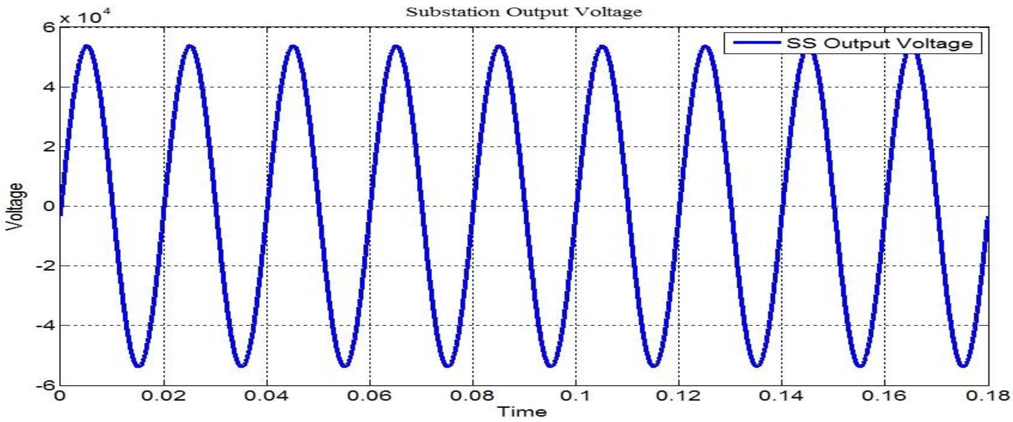

Fig. 8: Substation Output Voltage when the train is at 15 km

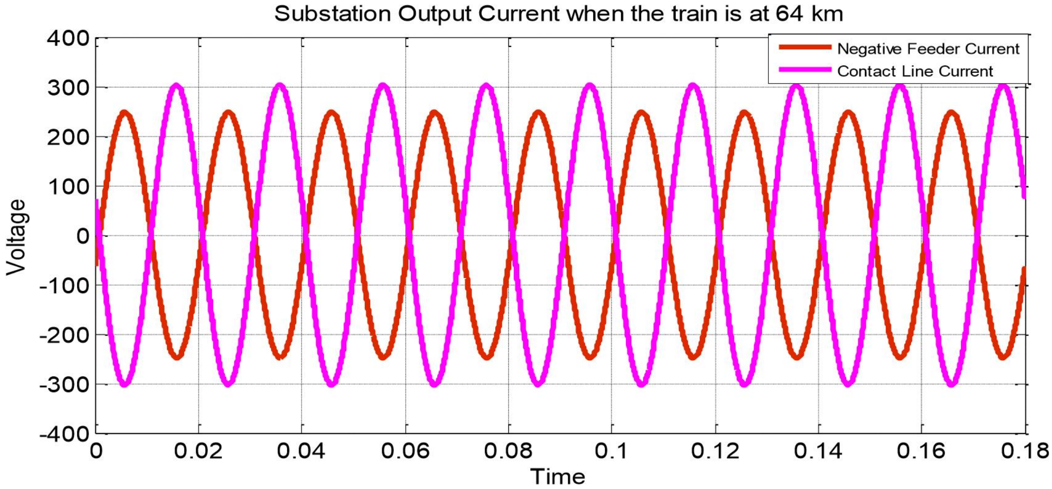

Fig 9: substation output voltage when the train is at 64 km

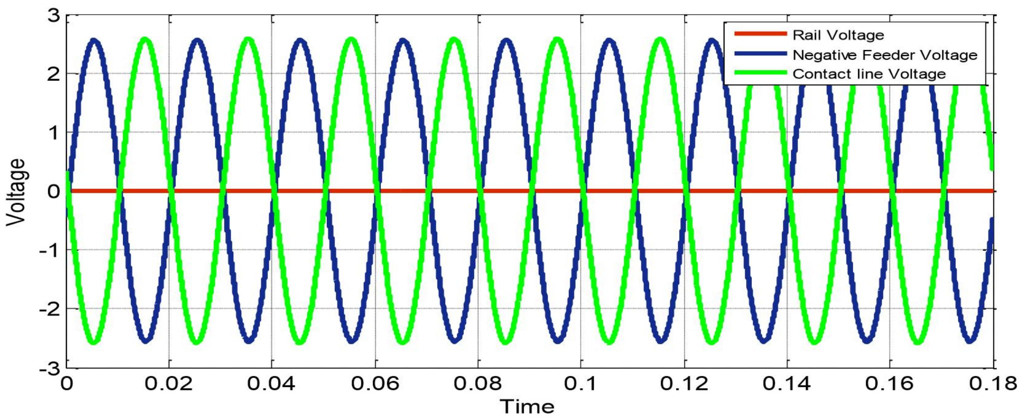

Fig. 10: Autotransformer 4 voltage when the train is at 45 km

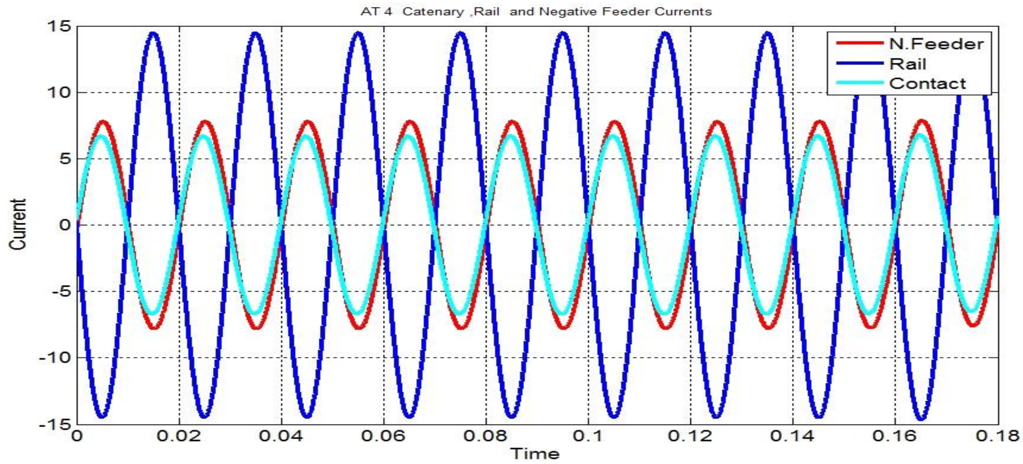

Fig 11: Autotransformer 4 currents when the train is at 45km

3.1.2 Observation

From the result gotten from the simulation shows that, a locomotive that is moving for 15km on its full speed retains the level of its current and voltage stays without reproducing the same wave into 2 to 4 wave like in case train on 45km to 65km. For both Ac and dc electric traction. DC traction drive goes for short distance unlike AC traction drive that go far distance this was caused due to some high amount of losses of current caused waving dropper wire on the railway, losses caused by inductive system like transformer (solid state).

4. CONCLUSIONS

It is clear that electric traction drive, are of DC traction drive and AC single - three phase electrical traction drive which are made base on the simulation results obtained with respect to voltage, current and percentage voltage regulation.

A detailed literature survey of a traction power supply system and its major components such as traction power transformer, the transmission line or the catenary system, and the moving loads together with related issues such as power demands of the load, voltage fluctuations range, load flow and other main subjects were reviewed and presented to summarize the state of the art techniques that are correlated to the methods proposed in this research.
In this study, the current and voltage value in general, have been varied with distance of electric locomotive and the number of train across the line. During simulation in worst-case scenario for voltage, 19.82 kV was observed that is well above the lowest permanent voltage likely to remain indefinitely recommended by BS EN 50163: 2004, which is 19 Kv. In worst-case scenario for current 414.63A was observed, which is well above the minimum recommended limit at any voltage in the range, as set out in EN 50388:2012 clause 7.2.

Finally, the simulation result shows the designed traction power supply system provided a significant operating margin. Minimum voltages and currents along the line having a single train or two trains or three cascaded trains at different locations from the traction substation are well above industry standards. In account of all this result, it is possible to conclude that the objective for design and simulation of traction power supply system.

4.1 Recommendation

Due to lack of real information, the models developed take some approximation and datasheet from international railway standard. Thus, by considering the actual information, we can improve the result obtained in this thesis. Regenerative braking can be considered. Regenerated energy is consumed by the other train in the same section; no damping resistor required. The model of a snapshot of the system can be used with little modifications to perform the more complex fault analysis and more detailed modeling of the system.

4.2 Knowledge added

Looking at traction drive their still things needed to be considered most especially on the electrical traction drive, since the DC traction drive (locomotive) can only go for short distance, to compare to single to three phase AC traction drive that can go for long distance. To improve the limitation on the side of the DC traction drive, the power engineer in charge of designing electrical system, should consider the possibility of sub-auxiliary inverter to each of the motor used.

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