ANN CONTROLLED DSTATCOM FOR POWER QUALITY ENHANCEMENT IN SENSITIVE LOCAL DISTRIBUTION GRID

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ABSTRACT

The present situation leads to a number of power quality problems due to the integration of renewable energy sources and the increase of non-linear industrial and commercial demands. Hospitals run sensitive, linear, non-linear, and unbalanced loads among the commercial utilities on the grid. In addition to being prioritized, these loads are diversified, which seriously impairs the local distribution system's power quality. It causes reactive power imbalance and harmonic injection because of its broad divergence. The Distribution Static Compensator (DSTATCOM) is suggested as a remedy for load balancing, neutral current compensation, reactive power imbalances, and harmonic mitigation. In order to enhance power quality in the local distribution grid, the current study uses an artificial neural network controller (ANN) to generate switching pulses for IGBT switches in the DSTATCOM. Additionally, the suggested method outperforms conventional PI controllers and fuzzy logic controllers in terms of harmonic mitigation. MATLAB software is used to model the proposed system in order to ensure its proper implementation.

INDEX TERMS: power quality, ANN, DSTATCOM, local distribution grid.

1.INTRODUCTION

1.1 General

Systems for distributing electricity are intended to function at certain, sinusoidal voltage and current levels [1]. The rising use of non-linear load caused by the adoption of new technologies is a significant power quality issue. In terms of equipment damage, current flow via neutral conductors, distortion in current and voltage waveforms, overheating, and power factor loss, non-linear loads often put the system under stress [2]. In general, high-quality electricity is necessary for healthcare institutions to run their loads more efficiently [3]. However, there are a variety of load concentrations in these medical facilities, including linear, non-linear, balanced, unbalanced, light, and heavy models. In addition, most of them are sensitive and controlled digitally [4]. It is not advised to make a conventional trade-off between operation and control. Switched Mode Power Supplies (SMPS), which are less susceptible to high power quality, are necessary for digital load management. Major power pollutants include heavy loads from devices like X-ray machines, CT and MRI scan machines, lighting loads in operating rooms, and equipment in intensive care units (ICU) and critical care units (CCU) [5].

These sensors operate in a way that, upon disconnecting, causes harm or even death to people [6]. Due to the heavy and inductive nature of most loads connected by commercial utilities, voltage sags and swells while switching loads. Custom Power Devices (CPDs) may be used to assist mitigate these power quality difficulties [7]. At the point of common coupling (PCC), power quality may be improved by injecting either current or voltage, or both, into the system [8]. The regulated terminal voltage that follows from this leads to an enhanced power factor. Different varieties of CPDs are available, including Dynamic Voltage Restorer (DVR), Distribution Static Compensator (DSTATCOM), and others [9]. DSTATCOM provides increased dependability and performance by adding the required reactive power. Compared to SVC and other CPDs, the DSTATCOM offers superior voltage support during the abrupt removal of heavy loads. The DSTATCOM precisely adjusts its output current regardless of the AC system voltage within a non-linear operational range [10]. The DSTATCOM can readily connect with energy storage devices such as huge capacitors, batteries, and fuel cells (FC) and responds flawlessly. In [11], a DSTATCOM interface with FC is suggested. Numerous kinds of control algorithms are available for DSTATCOM, and their topologies are covered in [12]. Instantaneous Symmetrical Component Theory (ISCT), Synchronous Reference Frame Theory (SRFT), and Instantaneous Reactive Power Theory (IRPT) are the most often employed theories. In [13], the control process based on the composite observer is described.

In [14], the neutral current compensation is handled via a zig-zag transformer in conjunction with the Euclidean Direction Search method (EDST) for VSC control. The Chebyshev functional expansion based artificial neural network (ChANN) method has been developed in [15] as a development of ANN. Controllers other than traditional PI controllers are recommended for efficient DSTATCOM control. Artificial intelligence (AI)-based controllers, including fuzzy logic controllers (FLC) and controllers based on artificial neural networks (ANNs), are described in [16], [17], and [18] compares the THD values with PI controllers. The suggested ANN can manage uncertainty better than Fuzzy Logic Controllers (FLC) [19], [20], in comparison to the AI controllers discussed above. Compared to other AI systems, this aids in producing exact output [21]–[23]. As a result, lowest THD may be reached since ANN Controller offers accurate system control [24], [25]. Our work has three main contributions to its credit:

• Development of ANN Controller-based DSTATCOM to improve Local Distribution Grid (LDG) power quality

• A thorough simulation analysis comparing the LDG's power quality with and without the suggested DSTATCOM

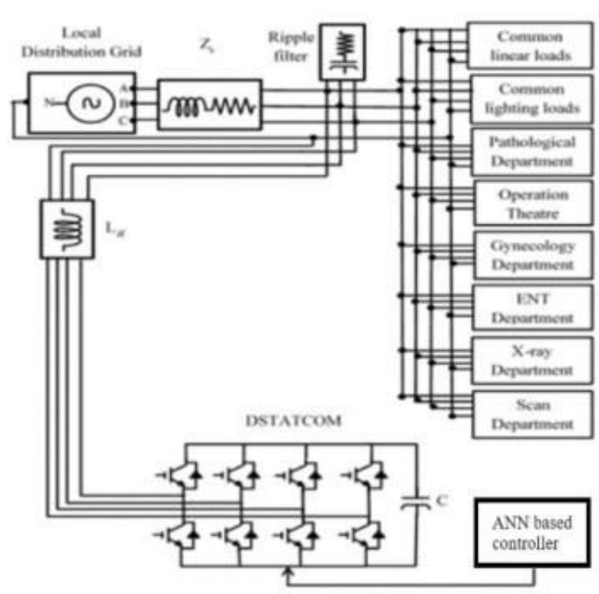

Fig 1.1 proposed circuit topology

The suggested DSTATCOM setup with the ANN controller is shown in FIGURE 1.1. The suggested RLS filter based ANN controlled DSTATCOM is compared with the traditional PI, FLC controlled DSTATCOM, and the harmonic spectrum is shown in detail.

The structure of the article is as follows. The study's system configuration model is covered in Section II. The loads that are linked to the system are then thoroughly analyzed. The design process for DSTATCOM, which will be used as a mitigating device, comes next. The control algorithm formulation for the DSTATCOM action is covered in full in Section IV. A thorough examination of the simulation's outcomes is provided in Section V. Furthermore, a comparative analysis of the suggested technique is conducted with other comparable approaches. In Section VI, the job is finally finished.

1.2 SYSTEM CONFIGURATION

Fig. 1 illustrates the modeling of a three-phase, four-wire local distribution grid (LDG) with sensitive hospital loads. Analyzing the loads at the medical facility and using an ANN Controller-based DC voltage controller in conjunction with an RLS filter is the main focus of the study. For load modeling, hospital real-time data is utilized. A mix of heavy, linear, non-linear, and unbalanced loads at different moments make up the suggested load model. Through the use of a step-down transformer, the hospital loads (415 V) are supplied with the 11 kV LDG. In order to aid with load balancing, reactive power compensation, neutral current, and current harmonic mitigation, a DSTATCOM is coupled in shunt with the LDG. For DSTATCOM, the reference current generator is the ANN Controller. The produced current removes the reactive part of the load. As a result, the reactive terms are removed from the source current component and only real terms remain. This results in the DSTATCOM relieving the generator of its reactive power load.

2.POWER QUALITY

The contemporary container crane industry, like many other industry segments, is often enamored by the bells and whistles, colorful diagnostic displays, high speed performance, and levels of automation that can be achieved. Although these features and their indirectly related computer based enhancements are key issues to an efficient terminal operation, we must not forget the foundation upon which we are building. Power quality is the mortar which bonds the Foundation blocks. Power quality also affects terminal operating economics, crane reliability, our environment, and initial investment in power distribution systems to support new crane installations. To quote the utility company newsletter which accompanied the last monthly issue of my home utility billing: ‘Using electricity wisely is a good environmental and business practice which saves you money, reduces emissions from generating plants, and conserves our natural resources.’ As we are all aware, container crane performance requirements continue to increase at an astounding rate. Next generation container cranes, already in the bidding process, will require average power demands of 1500 to 2000 kW – almost double the total average demand three years ago. The rapid increase in power demand levels, an increase in container crane population, SCR converter crane drive retrofits and the large AC and DC drives needed to power and control these cranes will increase awareness of the power quality issue in the very near future.

2.1 POWER QUALITY PROBLEMS

Power quality issues are defined as "any power problem that results in failure or misoperation of customer equipment, manifests itself as an economic burden to the user, or produces negative impacts on the environment" for the purposes of this article. Regarding the container crane sector, the following power-related problems deteriorate power quality:

Voltage transients, power factor, harmonic distortion, voltage swells and sags, and voltage dips

3.FACTS

In recent years, the term "flexible ac transmission systems," or "facts," has gained popularity as a way to describe power systems with increased controllability via the use of power electronic equipment. Around the globe, a number of factual devices have been released for diverse purposes. A variety of novel gadget types are now being implemented in real-world settings. Controllability is utilized in the majority of applications to prevent expensive or physically demanding expansions of power systems, such as upgrades or new substations and power lines. Facts-devices increase the use of already-existing installations and enable greater responsiveness to changing operating circumstances. Facts-devices are primarily used for the following applications: power conditioning, power flow control, voltage control, reactive power compensation, increased transmission capability, stability, power quality, power conditioning, flicker mitigation, and interconnection of distributed and renewable generation and storage systems.

The fundamental concept of transmission system facts is shown in Figure 3.1. Ideally, active power transmission cables should be used up to their thermal limitations. Several distinct information devices will be used to change the voltage and stability restrictions. As line length increases, the potential for fact devices becomes evidently more significant.

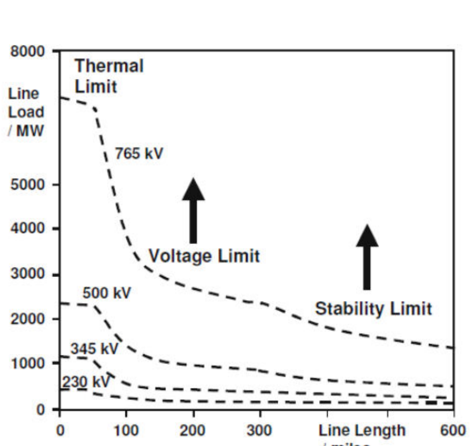

Fig 3.1: Operational Limits of Transmission Lines for Different Voltage Levels

4.FUZZY LOGIC

4.1 Fuzzy Logic

The range and quantity of fuzzy logic applications have grown dramatically in recent years. Applications include industrial process control, medical instruments, portfolio selection, and consumer goods including cameras, camcorders, washing machines, and microwave ovens. You must first comprehend what is meant by fuzzy logic in order to comprehend why its usage has increased. Fuzzy logic is defined in two ways. Fuzzy logic is a logical system that is a restricted application of multivalve logic. But when applied more broadly, fuzzy logic (FL) is almost the same as the theory of fuzzy sets, which deals with classes of objects whose membership depends only on degree and have soft bounds. From this angle, fuzzy logic in its strictest sense is a subset of fuzzy logic. Fuzzy logic is distinct from conventional multivalve logical systems in both idea and content, even in its more limited description.

4.1.1 What is fuzzy logic?

The core idea of fuzzy logic is the relative value of accuracy: When a rough response will do, how essential is it to be perfectly correct? To solve fuzzy logic issues, you may combine the MATLAB technical computing program with the Fuzzy Logic Toolbox software. Because fuzzy logic does a decent job of balancing importance and precision—something that humans have been doing for a very long time—it is an interesting field of study.

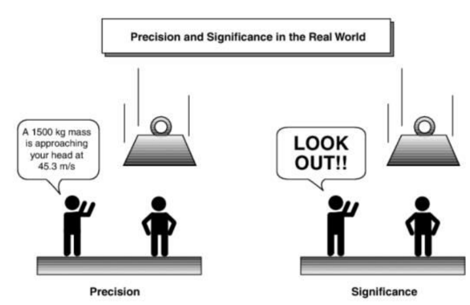

fig 4.1 fuzzy description

5.PROPOSED SYSTEM MODELLING

In the suggested task, load modeling is essential. There are balanced, unbalanced, non-linear, and linear loads in the hospital. A rectifier is used to link a number of DC loads to the AC supply. Hospital loads are very susceptible to problems with power quality. For the suggested method, many sorts of medical burdens [26] are taken into account. A variety of departments are available, including the intensive care unit, pathology, ENT, gynecological, X-ray, scan facilities, and more. Seasonal loads, continuous operation, critical loads, peak loads, and other variables all affect the system's overall load.

5.1. DC BUS VOLTAGE

Generally speaking, the amplitude of the AC voltage should be less than the DC voltage Vdc value. As a result, Vdc may be calculated using the PCC voltage at LDG. (1)[2] is used to compute the Vdc.

$$V_{dc} = \frac{2\sqrt{2}V_{LL}}{\sqrt{3}mi}$$

where VLL is the DSTATCOM's line-to-line ac voltage and m is the modulation index, which is set to one. With a VLL of 415 V, the calculated value of Vdc is 677 V. For this reason, 700 V is used as the DC voltage reference (Vdc).

5.2. DC BUS CAPACITOR

An essential component, the DC bus capacitor is made based on variations in the DC voltage. The design of the DC bus capacitor (Cdc) comes from (2) [2].

$$\frac{1}{2}C_{dc}\left[(V_{dc}^{*})^2 - (V_{dc})^2\right] = k3V_{ph}\,(aI)\,t$$

where an is the overload factor & a = 1.2, k = 0.1, t is the recovery period of the DC bus voltage & t = 0.04s, I is the phase current, and Vph = 240 V. After calculation, the value of Cdc is estimated to be 10,000 μF.

B. ANN CONTROLLER

Artificial Neural Networks are relatively crude electronic models based on the neural structure of the brain. The brain basically learns from experience. It is natural proof that some problems that are beyond the scope of current computers are indeed solvable by small energy efficient packages. This brain modelling also promises a less technical way to develop machine solutions. This new approach to computing also provides a more graceful degradation during system overload than its more traditional counterparts. These biologically inspired methods of computing are thought to be the next major advancement in the computing industry. Even simple animal brains are capable of functions that are currently impossible for computers. Now, advances in biological research promise an initial understanding of the natural thinking mechanism. This research shows that brains store information as patterns. Some of these patterns are very complicated and allow us the ability to recognize individual faces from many different angles. This process of storing information as patterns, utilizing those patterns, and then solving problems encompasses a new field in computing. This field, as mentioned before, does not utilize traditional programming but involves the creation of massively parallel networks and the training of those networks to solve specific problems. This field also utilizes words very different from traditional computing, words like behave, react, self organize, learn, generalize, and forget.

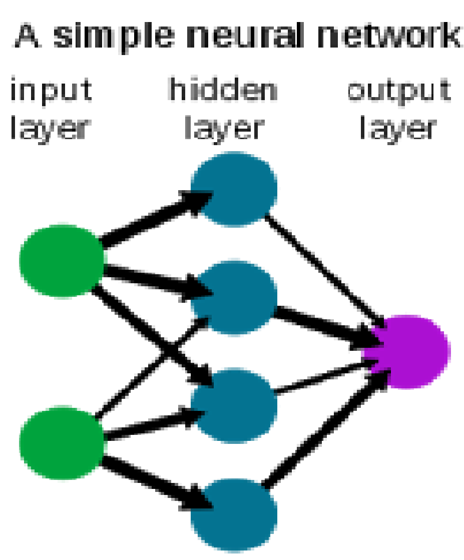

Fig.5.1 .Topology of neural network

Working of ANN:-

Currently, neural networks are the simple clustering of the primitive artificial neurons. This clustering occurs by creating layers which are then connected to one another. How these layers connect is the other part of the "art" of engineering networks to resolve real world problems. Basically, all artificial neural networks have a similar structure or topology as shown in Figure1. In that structure some of the neurons interfaces to the real world to receive its inputs. Other neurons provide the real world with the network's outputs. This output might be the particular character that the network thinks that it has scanned or the particular image it thinks is being viewed. All the rest of the neurons are hidden from view.

Training of ANN: -

Once a network has been structured for a particular application, that network is ready to be trained. To start this process the initial weights are chosen randomly. Then, the training, or learning, begins. There are two approaches to training - supervised and unsupervised. Supervised training involves a mechanism of providing the network with the desired output either by manually "grading" the network's performance or by providing the desired outputs with the inputs. Unsupervised training is where the network has to make sense of the inputs without outside help.

1. Supervised Training - In supervised training, both the inputs and the outputs are provided. The network then processes the inputs and compares its resulting outputs against the desired outputs. Errors are then propagated back through the system, causing the system to adjust the weights which control the network. This process occurs over and over as the weights are continually tweaked. The set of data which enables the training is called the "training set." During the training of a network the same set of data is processed many times as the connection weights are ever refined. The current commercial network development packages provide tools to monitor how well an artificial neural network is converging on the ability to predict the right answer.

2. Un supervised, or Adaptive Training. The other type of training is called unsupervised training. In unsupervised training, the network is provided with inputs but not with desired outputs. The system itself must then decide what features it will use to group the input data. This is often referred to as self organization or adoption.

Here we are using the supervised training ANN controller. The compensator output depends on input and its evolution. The chosen configuration has seven inputs three each for reference load voltage and source current respectively, and one for output of error (PI) controller. The neural network trained for outputting fundamental reference currents. The signals thus obtained are compared in a hysteresis band current controller to give switching signals.

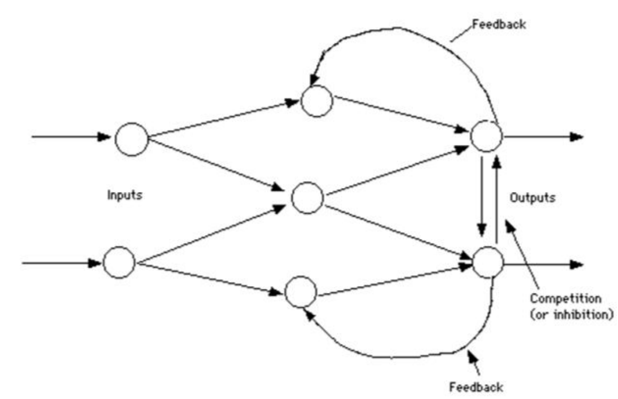

Figure.5.2 Simple Network with feedback and competition

Training is given as follows:-
net=newff(minmax(P),[7,21,3], {„tansig‟,‟tansig‟,‟purelin‟},‟trainlm‟);
net.trainParam.show =50;
net.trainParam.lr = .05;
net.trainParam.mc = 0.95;
net.trainParam.lr_inc = 1.9;
net.trainParam.lr_dec = 0.15;
net.trainParam.epochs = 1000;
net.trainParam.goal = 1e-6;
[net,tr]=train(net,P,T);
a=sim(net,P);
gensim(net,-1);

6.SIMULATION RESULTS CASE(1):

6.1 LDG with PI Controlled DSTATCOM

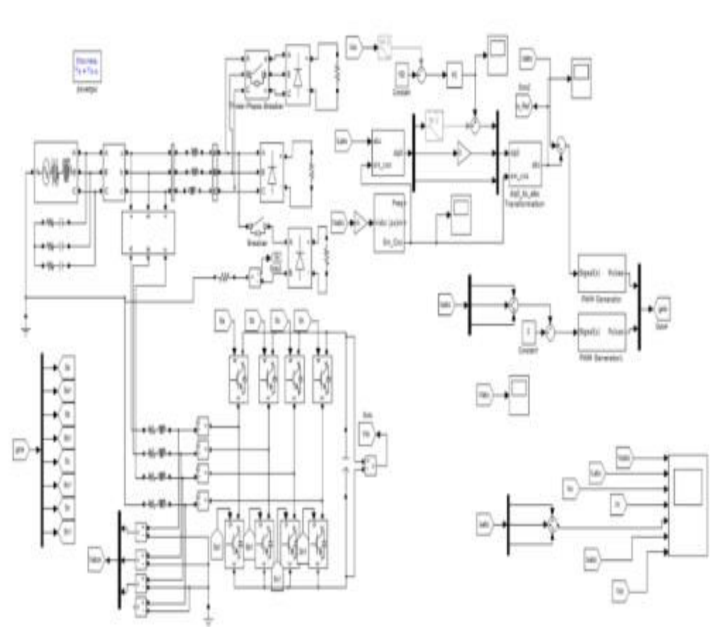

Fig.No.6.1: Simulation Model with PI Controlled DSTATCOM

6.2 SIMULATION RESULTS 6.2.1 Out put Wave Forms Of Grid Voltage, Load Current, DSTATCOM Current, Neutral Current

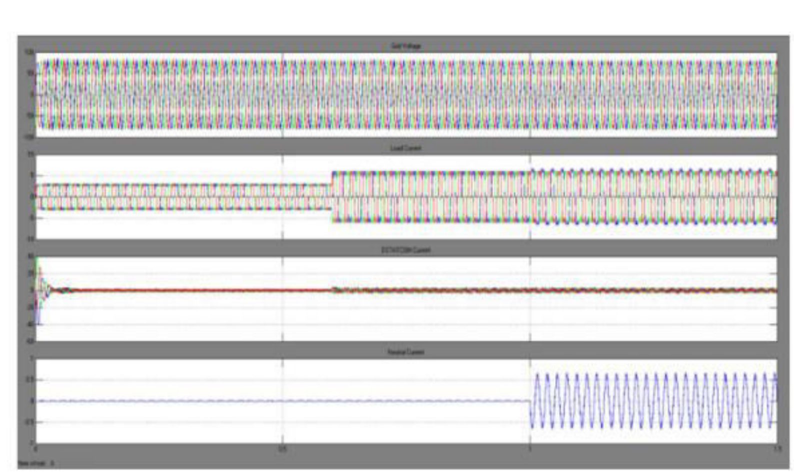

Fig 6.2: Out put Wave Forms Of Grid Voltage, Load Current, DSTATCOM Current, Neutral Current

6.2.1 Out put Wave Forms Of Load Voltage, Grid Current, DSTATCOM Voltage

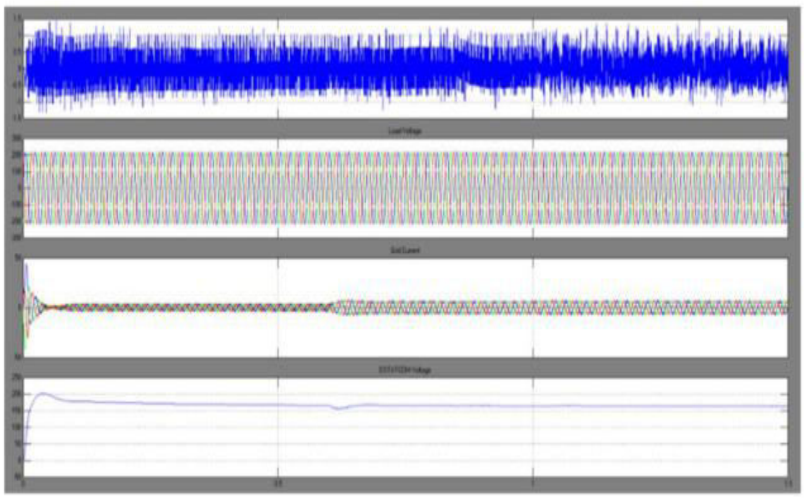

Fig 6.3: Out put Wave Forms Of Grid Current, Load Voltage, DSTATCOM Voltage

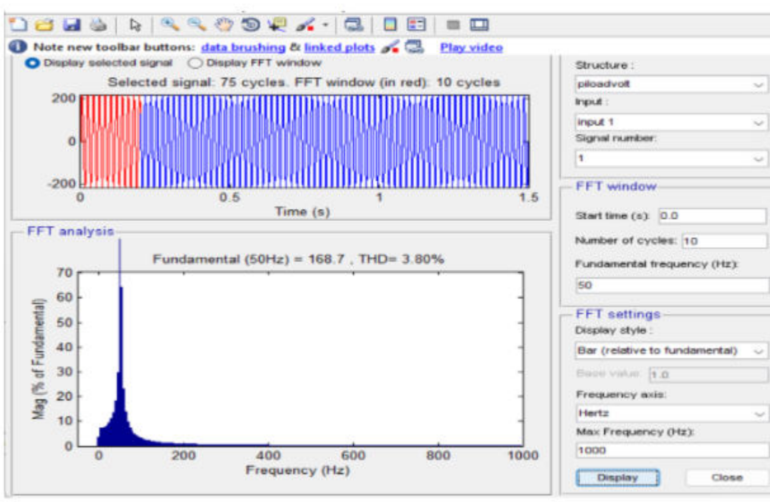

Fig 6.4: FFT Analysis Window(THD Measurement)

CASE(2):6.3 LDG with FLC Controlled DSTATCOM

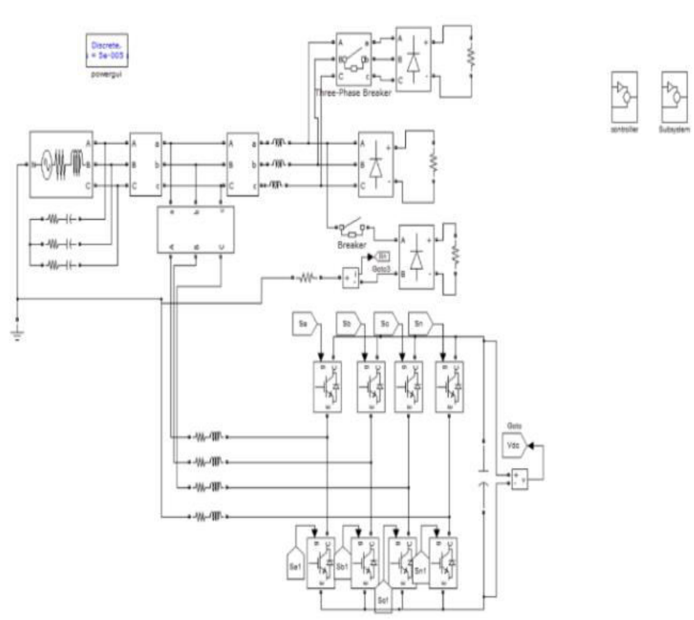

Fig 6.4 SIMULATION MODEL OF FLC CONTROLLED DSTATCOM

CASE(3): 6.4 LDG with ANN Controlled DSTATCOM

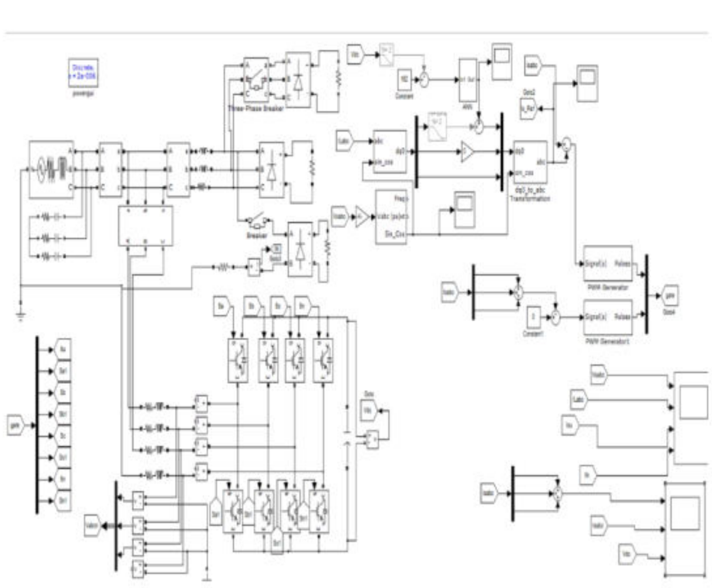

Fig 6.5: SIMULATION MODEL OF ANN CONTROLLED DSTATCOM

6.5.1 Out put Wave Forms Of Load Voltage, Grid Current, DSTATCOM Voltage

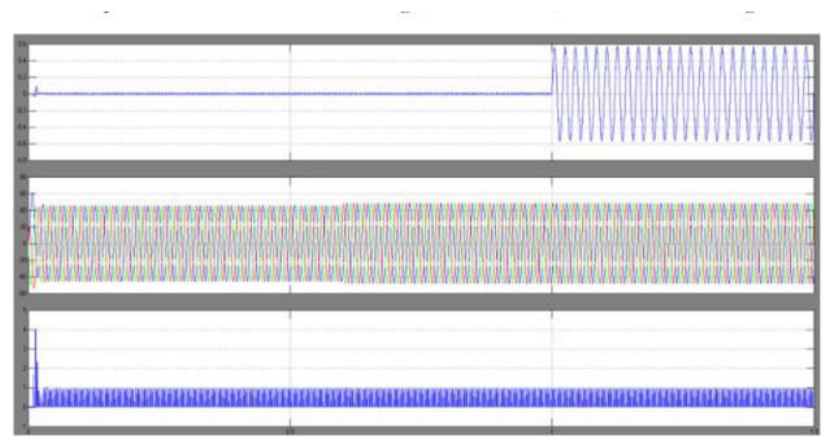

Fig 6.6: Out put Wave Forms Of Grid Current, Load Voltage, DSTATCOM Voltage

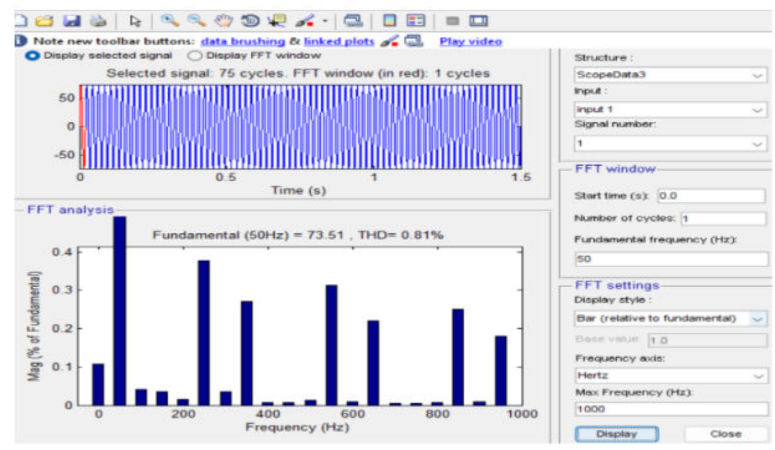

Fig 6.7: FFT Analysis Window(THD Measurement)

7.CONCLUSION

This research has validated the efficacy of ANN-based DSTATCOM deployment in improving grid stability and power quality when coupled to sensitive loads, as shown by its improved performance. In order to provide effective harmonic reduction, the ANN controller dynamically adjusts to changing grid circumstances, demonstrating an advanced degree of flexibility and learning capacity.The simulation findings demonstrate that the ANN-based DSTATCOM outperforms traditional controllers like PI and T1FLC in terms of overall harmonic distortion (THD) reduction across the system. This efficiency is explained by the ANN's ability to anticipate and proactively address disturbances, which significantly lowers the harmonic components of currents at the source side and improves the waveform profiles of voltage and current.Furthermore, the ANN controller's adaptive nature makes it easier to respond quickly and precisely to imbalanced loads, which is essential for preserving balanced neutral current flows. The operational improvements offered by the fourth leg of the VSC supplement this and help with the mitigation process even further. The condensed data make it abundantly evident that THD levels are constantly lower with the ANN-based DSTAsTCOM than with standard PI and FLC controllers at different times.

8.REFERENCES

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