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Neural Network Harmonic Filter for Microgrid System

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Keywords: Active Filter, Neural Network, Total Harmonic Distortion, Microgrid

Abstract: Development of electrical technology, especially converters technology, has made significant change in the characteristics of electrical power systems. Moreover, the need of converting electrical signal from pure sine to distorted sine from renewable energy based generators makes the use of converter technology increase. Currently, the use of renewable energy based power plants together with traditional generators has become commonplace, commonly known as microgrid systems. This is intended to improve efficiency, reduce environmental pollution, and preserve nature. Microgrid systems have a very positive impact on the electric power system. However, microgrids also cause negative impacts such as harmonics. This research is developing active filter based on Neural Network concept. Neural Network is used as control strategies to produce signals opposite harmonic signals. The simulation results show that the active filter based on neural network can reduce the Total Harmonic Distortion (THD) in microgrid systems effectively.

1 INTRODUCTION

Development of electrical technology makes significant changes in the characteristics of electrical power systems. This is due to the dominance of the use of digital technology in each sector. Digital technology, especially converter technology, has changed the nature of the electrical signal from pure sine to distorted sine (Chakir, Kamwa et al. 2014; Anwar, Elrayyah et al. 2015; Hashempour, Savaghebi et al. 2016; Gonzatti, Ferreira et al. 2017). The more affordability of renewable energy based generators makes the use of converter technology increase.

Currently, the use of renewable energy based power plants together with traditional generators has become commonplace, commonly known as microgrid systems (Abdelsalam, Massoud et al. 2011; Li, Li et al. 2016; Cao, Zhang et al. 2018; Feng, Zeng et al. 2018). This is intended to improve efficiency, reduce environmental pollution, and preserve nature (Dudurych, Rogers et al. 2012). Microgrid systems have a very positive impact on the electric power system. However, microgrids also cause negative impacts such as harmonics. Harmonics can be systemically detrimental if it is not well controlled (Setiawan et al. 2015).

Regarding to minimizing the negative effects of harmonics, many researchers have developed filter technology, both passive filters and active filters. Active and passive filters have their own advantages and disadvantages. One of the advantages of passive filters is relatively cheaper price, but passive filter applications only work effectively under relatively constant loading conditions, which are common in industrial areas. As for the active filter, the price is quite expensive, but it can be applied to various loading patterns.

This research developed an active filter by employing abc-dq transformation. The advantage of using dq frame is the signal will be easier to control because the value in dq frame is not influenced by time, which is very different from value in abc frame that changes by the time.

In this paper, Neural Network (NN) control was examined to replace the PI controller for controlling the active power filter. Simulation was performed in MATLAB after training the neural network (supervised learning) and it is shown that results are acceptable and applicable in grid system. Compared to PI controller, the NN controller can be less complicated and less costly to implement in industrial control applications (Setiawan et al. 2009).

2 LITERATURE REVIEW

2.1 Modeling of Microgrid Systems

Microgrid systems in this paper are operated stand alone, with three components of power plant. The first is conventional power plant (diesel power plant), the second is direct photovoltaic (PV) systems, and the third is PV systems with battery.

2.1.2 Diesel Power Plant Model

Diesel power plant (DPP) model is generally constructed by a diesel engine and synchronous generator (SG). The complete dynamic model of DPP requires modelling diesel engine with speed control and SG with the system voltage control as well as clutch between the SG and diesel engine as shown in (Fig.1) [15-16].

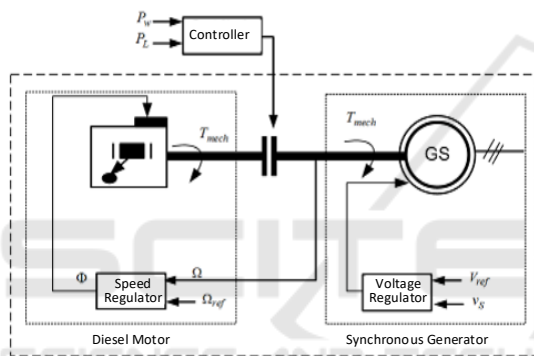


Figure 1: DPP model

2.1.2 Photovoltaic Systems Model

The electrical power generated and terminal voltage of Photo Voltaic (PV) module depend on solar radiation and ambient temperature. The equivalent electrical circuit describing the solar cells array used in the analysis is shown in (Fig.2).

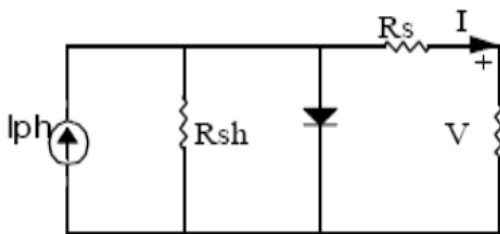


Figure 2: PV equivalent circuit

2.1.3 Modeling of Battery Storage System

In this work, it was developed a model of the Ni-MH electrochemical battery. The equivalent circuit of the battery storage system is presented as in (Fig.3) [19]:

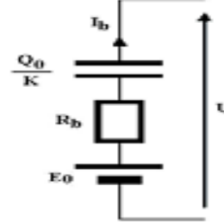


Figure 3: Electrical equivalent model of the battery

The simulation of this paper is aimed to show the effectiveness of proposed method to reduce total harmonic distortion (THD) referring to IEEE 519-2014. The harmonics source simulated in this paper was harmonics that were produced by rectifier. The rectifier model can be explain as follows:

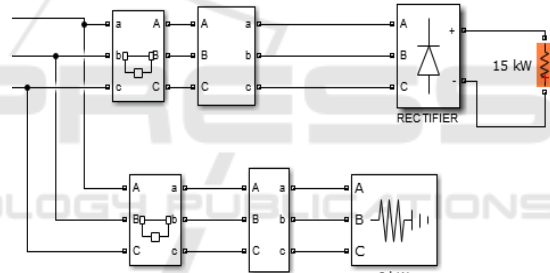


Figure 4: Load model

In this simulation, there were two kinds of load model. The first model is linear load containing R, L and C. The second model is non-linear load containing power converters.

2.2 Modeling of Harmonic Filter

Filter used in this simulation is harmonic active filter. There are two types of harmonic filter modeling. The first one is harmonic filter modeling based on Proportional Integral (PI) control. This type was used as comparison method to verify proposed method performance. The second modelling is harmonic filter based on Neural Network (NN). This type is proposed method.

2.2.1 Harmonic filter based on PI controller

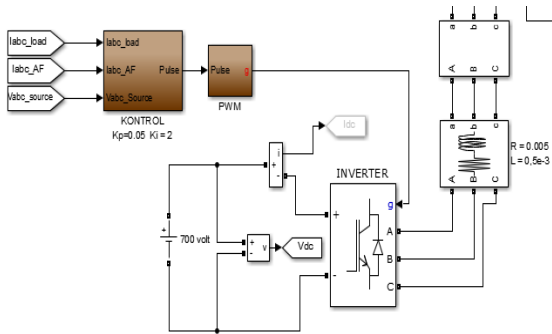


Figure 5: Model of Active Harmonic Filter

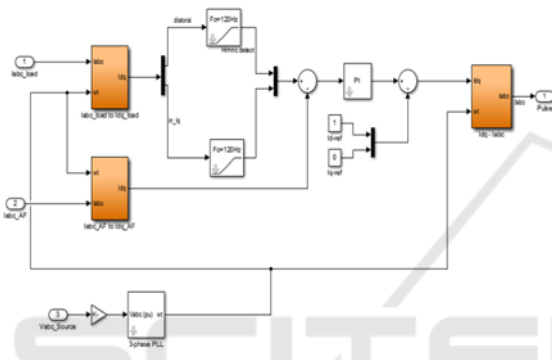


Figure 6: Model of Proportional Integral (PI) controller for Active Harmonic Filter

2.2.2 Harmonic Filter Based on Neural Network

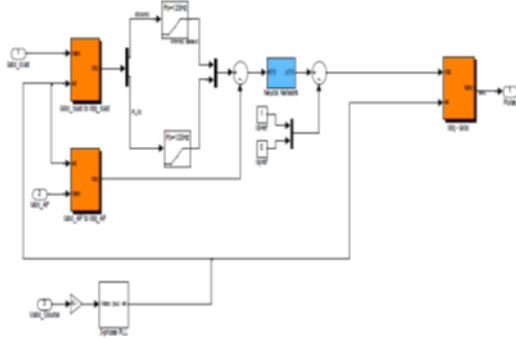


Figure 7: Model of Neural Network (NN) Controller for Active Harmonic Filter

2.3 Neural Network Training Process

Structure of Neural Network used in this simulation has four inputs and two outputs. The inputs are load voltages/currents in d-q frame and APF (active power filter) voltages/currents in d-q frame. NN is employing single hidden layer with 7 neurons for modelling control strategy. Sigmoid function is used as activation function. Sample data used as training data is given in (Fig.8).

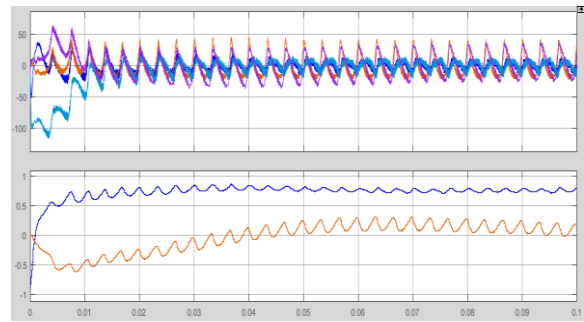


Figure 8: one of some pattern of training data

For convenience of data presentation, the data training is provided in the graph to reduce number of table rows due to the huge numbers of training data. The upper box graph of Fig.9 is the input data and the lower box graph of Fig.9 is the output. The verification performance of proposed method is conducted in the next section.

3 RESEARCH METHODS

This paper is aimed to simulate the reduction of THD (total harmonics distortion) in Microgrid systems using active filter that was designed in dq frame and controlled using NN (Neural Network). The NN controller that was designed in this paper had 4 inputs and 2 outputs. The inputs were load signals in dq frame and APF (active power filter) signal in dq frame. The output was the controlled signals representing source signals. This signal was driven to pure signals. The complete design of simulation, including power generation model, load model, and filter model, is expressed in the flowchart at (Fig.9).

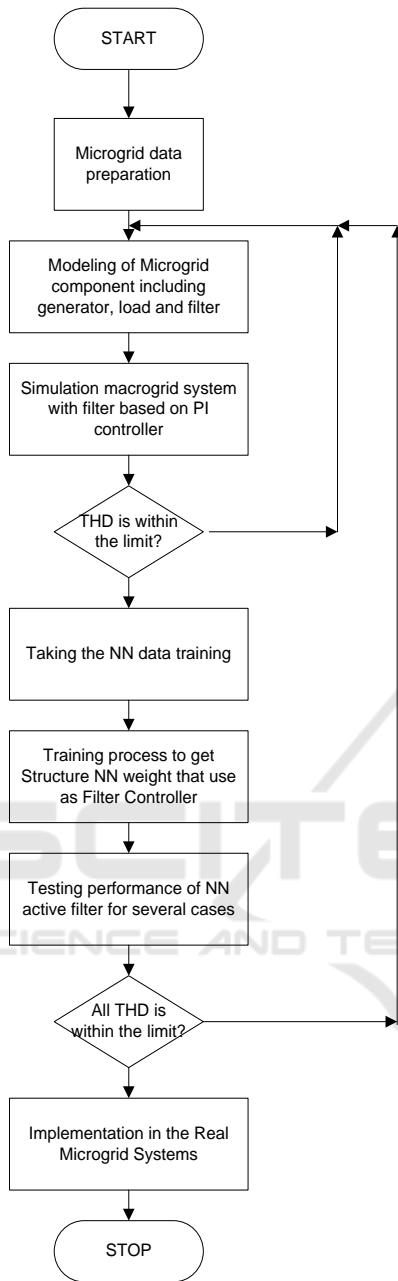


Figure 9: Research Flow Chart

Several procedures simulated in this chapter are aimed to verify the performance of active harmonic filter based on Neural Network (NN). The microgrid system used in this simulation is operated stand alone (off grid). The microgrid power plant is combination of diesel power plant, PV and PV plus battery. All the load models used in this simulation were rectifier. Microgrid model used for simulation is described in (Fig.10).

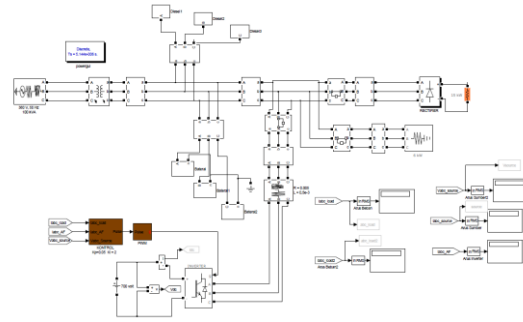


Figure 10: Model of Microgrid System

4 RESULTS AND DISCUSSION

There were two kinds of signal that were evaluated in this simulation. The first was voltage signal and the second was current signal.

4.1 Voltage signals simulation

The original signal voltage before control strategic was applied. is shown in (Fig.11).

In this step, the load is modelling for producing high level of Total Harmonic Distortion (THD). From (Fig.11), it can be seen that the THD level was 31.06%. This simulation is aimed to reduce the THD using PI controller in comparison to NN controller.

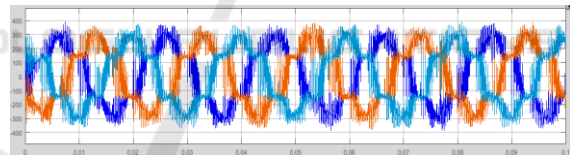


Figure 11a: The current signals before control action is implemented.

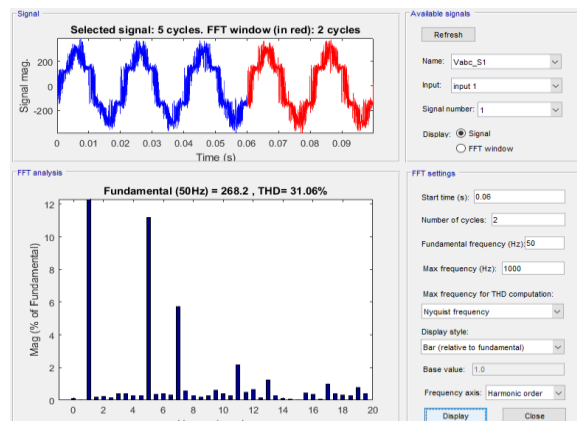


Figure 11b: The THD current before control action is implemented.

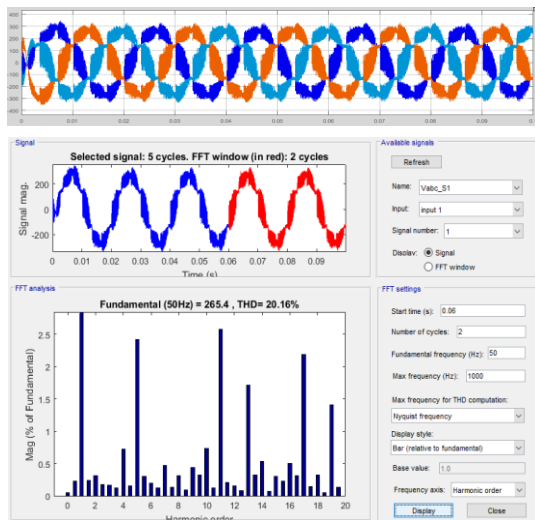


Figure 12: Voltage signals resulted by PI controller.

The signals voltages in (Fig.11) were controlled using PI controller. The model of PI controller can be seen in (Fig.7). The result is provided in (Fig.12). From the figure, it can be seen that the THD was decreased from 31.06% to 20.16%. The THD level in this case was still far from the IEEE 519 standard, but from the result, it can be concluded that the PI controller can reduce the THD to 33.16%.

The next simulation was controlling voltage signals in (Fig.11) using NN controller. NN controller model can be seen in Fig.8 and the result can be seen in (Fig.13).

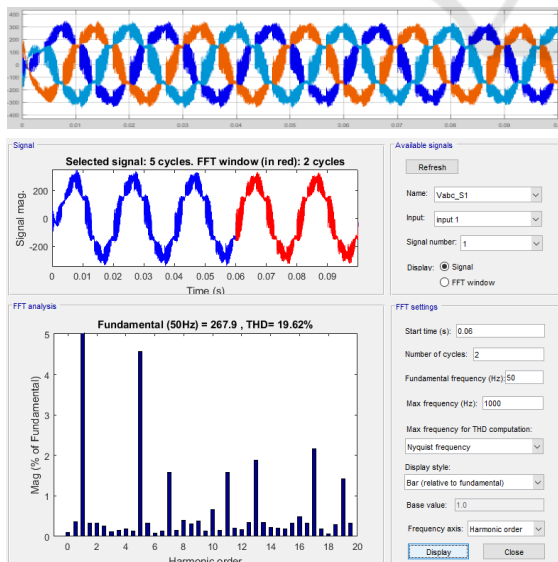


Figure 13: Voltage signals resulted by NN controller.

From the Figure, it can be seen that the THD decreased to 19.62 %. This result has shown that using NN controller can reduce THD better than by using PI controller. By using NN controller, it can reduce THD to 34.95 %. So, it can be concluded that in this case, NN controller is better than PI controller.

4.2 Current Signals Simulation

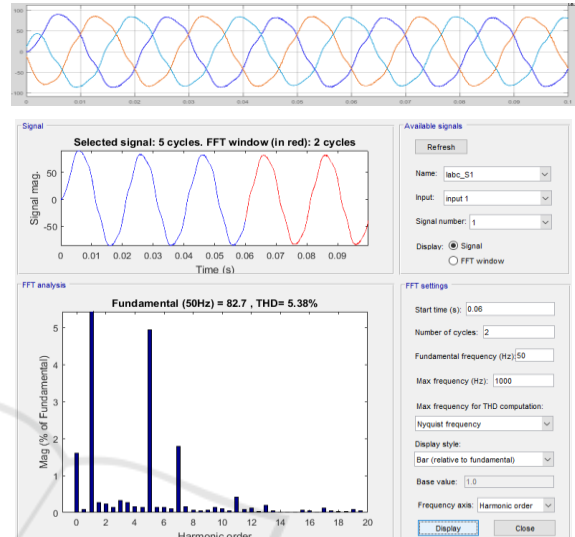


Figure 14: The current signals before treated by controller.

The current signals used as signals test in this simulation can be seen in the (Fig.14). From the figure, it can be seen that the signal had THD 5.38 %. This signal was little bit over IEEE 519 standard. The signal was then treated using PI controller. The signal resulted by PI controller can be seen in the (Fig.15).

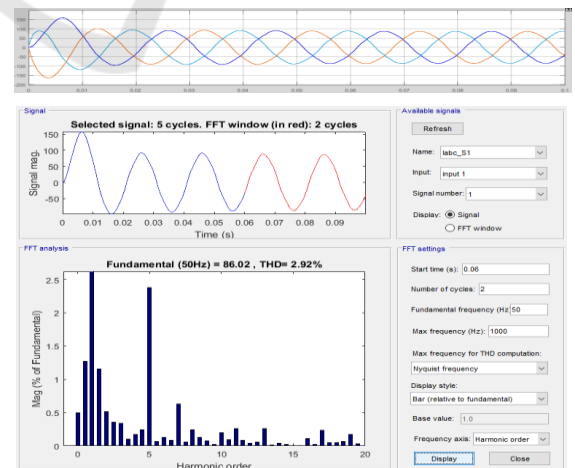


Figure 15: Current signals resulted by PI controller.

Figure 15 gives information that THD current decreased from 5.38% to 2.92 %. According to the IEEE 519 standard, this signal was within the standard.

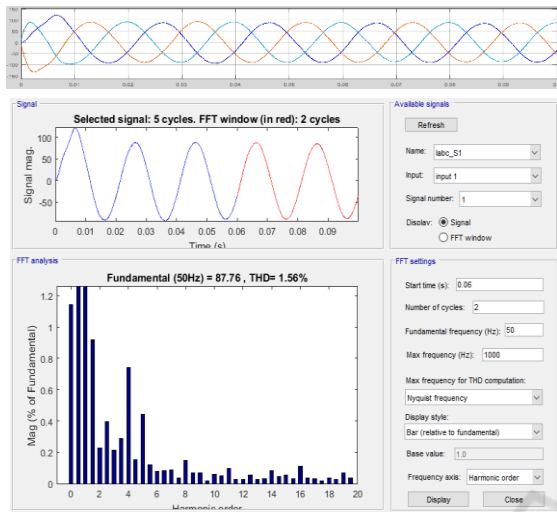


Figure 16: The current signals resulted by NN controller.

The current signals in Fig.14 were also controlled by NN controller and the results can be seen in the (Fig.16). From the figure, it can be seen that the THD current decreased to 1.56 %. This simulation has also proved that the NN controller gives better performance than PI controller does. In this case, the PI controller can decrease signal by 45.72 % while NN controller can decrease THD level by 71%.

5 CONCLUSION

From the simulation results provided in section 3, it can be concluded that the proposed methods, abc-dq frame transformation and NN controller of Active Harmonic Filter, have better performance in comparison to PI controller of active Harmonic Filter. In the voltage cases, the PI controller can reduce THD by 33.16 % while NN controller can reduce by 34.95 %. In other hand, in the current cases, the PI controller can reduce THD current by 45.72%, while the NN controller can reduce by 71%. According to these data, the proposed method is recommended as method for reducing THD, either THD voltage or THD current.

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