ANFIS Based Dual Unified Power Quality Conditioner to Mitigate Voltage SAG/SWELL and to Improve the Power Quality of the System

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Abstract— The project mainly describes the utilization and the advantages of the adaptive neural fuzzy inference system while the application of the same is done at the dual unified power quality conditioner. The basic idea of compensating for the power quality issues like voltage sag and swell will remain same but the controlling part that was involving with a PI controller initially will be replaced with an adaptive neural fuzzy inference system. The ANFIS system will be trained using the same PI controller output only and it will be designed or more specifically it will set its own rules based on the output it is getting from the PI controller. The two different inputs that this ANFIS will take up are one from the same steady state error evaluation block and the other the derivative block involved which is for the change in the error value with dynamic changes in the system behaviour. The same conditions like as of the PI controller is checked with the ANFIS and the output graphs are plotted for various cases. The output compensation graph is seen for the case and from that it could easily be make out that the voltage compensated waveform is having a greater system response compared to the PI controller and the output voltage starts hitting the magnitude which was given as the reference in the parallel active filter quite earlier than the other controller. One more advantageous feature of this same controller could be noted down while be calculating for the THD. The THD values variation could easily be seen for the ANFIS. A MATLAB/SIMULINK concept will be proposed here along with the comparison study for the both the controllers and various cases of the power quality issues will be checked.

Key words: ANFIS Based Dual Unified Power Quality Conditioner, SAG/SWELL

I. INTRODUCTION

As we have seen a few decades ago people who concerned about the power quality issues and its detrimental effects were very less. Not long ago people became so curious about the quality of the power that each and every individual who is receiving the facility served from the utility or maybe his own generated is asking about the quality of power. As we can even see the drastic change in our own day to day life consumption of electricity has been increased from where it was a twenty years back.

The tremendous increase in the utilization of power quality conditioner has increased through-out the power system compared to a few years back. The main reason behind this increase in the usage is the low power quality that has been served and the inherent issues that comes within low power quality like of voltage sag, voltage swell, the harmonics associated and the imbalance of the system voltage. As we know most of the equipment recent days no matter it is from the industries or the normal individual are from the background of power electronics. And at the same time the proportional use of non-linear loads also adds up to the cause and make the issue a bit more serious. The nonlinear loads draws current with a fundamental harmonic component and it distorts the load current and which in turn helps in distorting the other sensitive loads associated.

The voltage sag and swell are like the other power quality issues that are quite common in current time's power system. The sag is the phenomenon when the voltage waveform of the system succumbs to a decrease in the amplitude of the voltage and in swell the waveform experience a with an increase in the magnitude for a particular time period if the fault occur that particular period or any other cause that makes it to suffer from those two issues. These two cases could be quite severe for a power system equipment, because of these two the sensitive equipment might suffer from a sudden breakdown. The equipment relays, variable frequency drives can be damaged due to reduction or sudden increase in the voltage value. This might permanently damage the equipment. This type of behaviour is not suitable for the system or not even the industries from the economical point of view. The industry might lose some of its costly equipment and this could be really bad for the progress of the company.

So the use of power quality conditioner in such kind of a situation will certainly try to mitigate all the issues which has been discussed earlier. It will help in maintaining load voltage with less amount of distortion and a balanced one and even at the same moment draw from the grid very less distorted currents even though the load side and the grid does have the harmonic contents.

The conventional unified power quality conditioner that was initially designed to have the configuration where the filters were used with the series active filter controlled as the voltage source and the parallel active filter as the current source. Usually the series active filter was used to compensate for the grid side voltage dis-balance and the parallel active filter to compensate for the load side distortion. The compensated voltage and currents in this case will contain harmonics in itself and even the references will also have the harmonics. The references obviously will be generated using a very complex calculation of reference generation. [4],[7],[9],[2],[5]

Dias obviously in his paper talked about the technique of sinusoidal reference generation so that the complexity of the reference generation could be avoided. In his paper that problem worked out well but one more point came to notice was the leakage impedance of the connection transformer which was creating a problem in the voltage compensation as it was in use.

The next paper presented by Moran [10] in the year 1989 talked about a dual current source inverter based line voltage conditioner in which he tried the opposite controlling technique that means controlling the series active filter as current source and the parallel active filter as voltage source. The same idea was used by so many authors on unified power quality conditioner [8] and some on the uninterruptible power sources [6], [3]. The same work has been deeply carried out by Aredes [11] who discussed about a 3phase unified power quality conditioner and he named it as iUPQC. The advantage of this type is that it deals with the sinusoidal waveform and the controls involved the p-q theory which is a bit complex.

The idea about this project was taken mainly from the paper described by Raphael [1] where a dual 3-phase structure of the unified power quality conditioner was presented along with a hardware modelling of the project. The paper presented a PWM technique control for the distribution system. The paper presented the various cases of voltage dip, rise and load shifting and with the help of power flow structure of the project and a pre-charge sequence.

A. The Idea of the Conventional Control

The conventional control of the unified power quality conditioner was initially discussed with the series active filter and the parallel active filter, the series being the voltage control and parallel being the current control. The series for compensating the grid distortions and to have a load voltage with only the fundamental content.

The parallel filter is supposed to be current controlled and this has to drain all the harmonic contents and that are there in the load current. This helps in keeping the current waveform sinusoidal.

B. Problem Formulation with the Conventional Control

The project about which we are about to write the problem formulation has a few disadvantages which needs to be taken care of so that the main motive of the project could be fulfilled which is compensating for the various types of PQ issues. The previous control which was discussed has some of the following disadvantages-

1) The reference which has been generated for both the filters were not sinusoidal and it has its own harmonic content. So while going for the harmonic reduction it could not have been proper. But to get rid of this in the new control the references which are considered are completely sinusoidal in nature and the pulse width modulation scheme will also deal with a familiar kind of spectrum which is good for the project.
2) The next problem which it faces is from the connection transformer, the connection transformer is used in conjunction with the series active filter. But the leakage impedance of the transformer was causing trouble while going for the voltage compensation as the SAF initially was used to compensate for the voltage. But the problem has been remedied here in the newer control by changing the way to control. Now the series active filter will be controlled as a current source and the other as a voltage controlled. So the series one initially will act as the high impedance path for all the harmonic contents. And it will be dumped in the connection transformer. So we will get a load voltage free of everything as the load voltage will be the difference of the source and the connection transformer voltage. The parallel active filter will act as the low impedance path and all the load harmonics will flow through the path leaving the load current free of harmonics.
3) And one more problem with the old way is that the reference generation for the voltage and current was quite complex. That problem also up to some extent has been taken care of but it also has a complex reference generation strategy employed to it.
4) The next problem which it faces is from the connection transformer, the connection transformer is used in conjunction with the series active filter. But the leakage impedance of the transformer was causing trouble while going for the voltage compensation as the SAF initially was used to compensate for the voltage. But the problem has been remedied here in the newer control by changing the way to control. Now the series active filter will be controlled as a current source and the other as a voltage controlled. So the series one initially will act as the high impedance path for all the harmonic contents. And it will be dumped in the connection transformer. So we will get a load voltage free of everything as the load voltage will be the difference of the source and the connection transformer voltage. The parallel active filter will act as the low impedance path and all the load harmonics will flow through the path leaving the load current free of harmonics.

II. THE DESIGN FOR THE DUAL UNIFIED POWER QUALITY CONDITIONER

The basic schematic representation of this type of "dual unified power quality conditioner" is quite the same as that of the previous normal unified power quality conditioner. But the one and only difference comes while going for the design of the project. As discussed so many times earlier the controlling section for the project is different from the conventional way of control. The way the filters are being controlled is opposite of that of earlier control. The simple circuit diagram representation of the project is shown below.

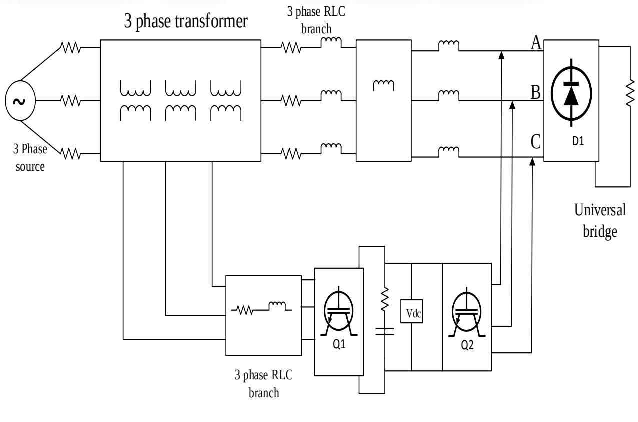

Fig. 1: The simplified block of dual UPQC

The 3-phase source along with the connection transformer and the filters has been shown in the block representation. The representation has kept just up to a schematic level.

III. ANFIS BASED CONTROLLER

This ANFIS is quite similar to fuzzy if we talk about the functionality of the controller, but still it has some the advantages which makes it more useful than the normal fuzzy. ANFIS stands for "adaptive neural fuzzy inference system". It actually combines both the application of the artificial neural networks and a bit of fuzzy logic. It comes under the category of TAKAGI SUGENO type inference system. It largely comes into the picture in the late 1990's. This kind of fuzzy is very helpful and we don't even have to worry about the changes in the input values because initially somewhat changes in the values, the output values was changing too. It means the MF associated with it will change its shape. But now with ANFIS there is no problem with that, if we have an already existing mathematical model or any model we can configure this with the neuro fuzzy system and it will change automatically for the system.

This type of controller has a learning procedure within it, and is called the training of the data. This training will take some time if the number of data's are more. The ANFIS editor will help in training the data's which could be retrieved by using the command window. This ANFIS helps to build an inference system where already the MF will be tuned by using the defined algorithm for the ANFIS. This will allow our fuzzy to gather the knowledge from the modelled data's. A derivative input is used to calculate the error so that we can check whether the modelled I/O data's are proper or not. It uses a "hybrid learning algorithm".

IV. MATLAB/SIMULINK DIAGRAM

The below figure shows the modified MATLAB simulated diagram for the ANFIS based control system for the project. The initial ANFIS will be trained by designing the workspace and setting the parameters properly for the workspace. The sample tie will be set accordingly which was there for the PI control. Then the derivative input is taken for the process and the output will be connected as shown below in Fig

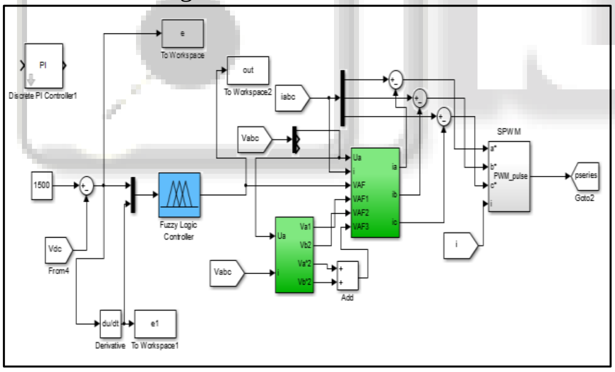

Fig. 2: Fuzzy logic control MATLAB block

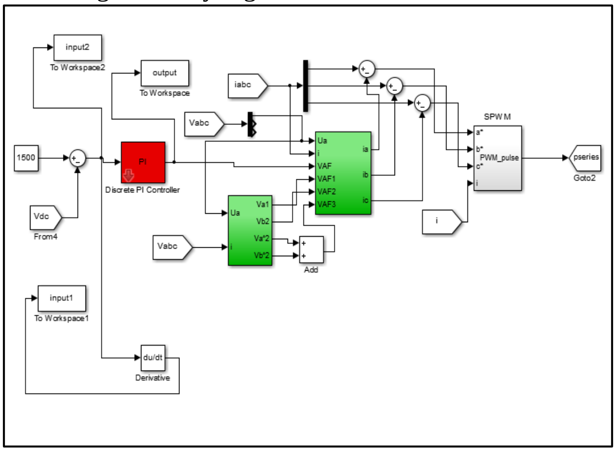

Fig. 3: Training MATLAB diagram for ANFIS

That's how the ANFIS will be trained and then generated "FIS" will be stored in the name of the project. So that next time when we will design the fuzzy control for the system then we can get the train variables form the same file or we can access them by just giving the same file directory for the fuzzy. The name will redirect the control to then values and it will use the values according to the rules set to give us the desired output.

V. RESULTS

The simulation study has been done for all the cases of various power quality issues like the initial controller and the graphs are plotted for the cases. The verification has been done for all the cases and it is found that the results which we got with the fuzzy controller is almost near about the same and in terms of the response or the quickness it is quite faster than the previous controller. The various graphs along with their explanation has been plotted next-

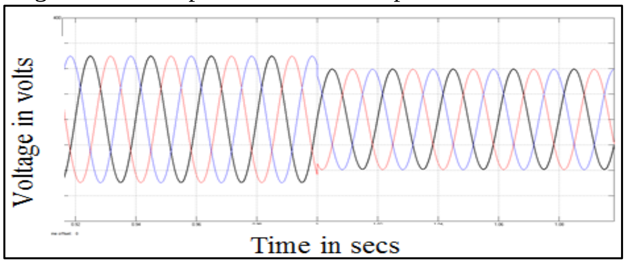

Fig. 4: The sag injected for the system

The above graph is showing the case for the voltage sag case which is introduced at the time exactly being 1.0 s. The dip in the voltage magnitude we can see from the figure. The sudden decrease in the phase voltages would rise to these type situations and these has to be remedied. The next case will be plotted for the swell-

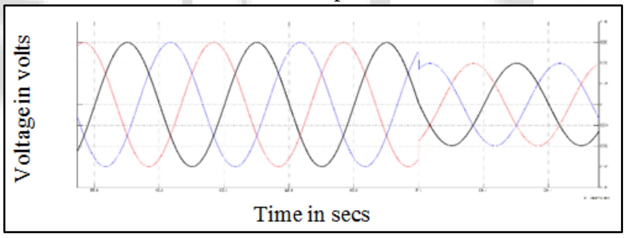

Fig. 5: Swell introduced for the system

The figure here is depicting for the swell case which is introduced at 1.5 s. Here also the sudden rise in the voltage magnitude could be seen clearly. So both the has to be mitigated after the proper compensation application and the results for that is plotted below.

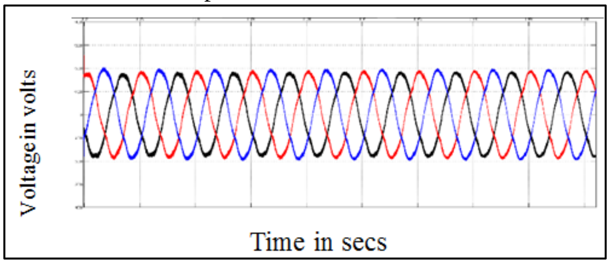

Fig. 6: Compensated waveform for the system

The compensated has waveform has been shown here and for the same we can see easily that for all the cases that was there initially now has been compensated quite well. Though the waveform is not quite proper sinusoidal as because the harmonic content in the wave is still exist, but the extent of compensation is negotiable. The further study on the total harmonic content is also done by using the FFT window. For that we are saving the graphs to workspace and then from that we are generating the FFT. The analysis has been plotted next.

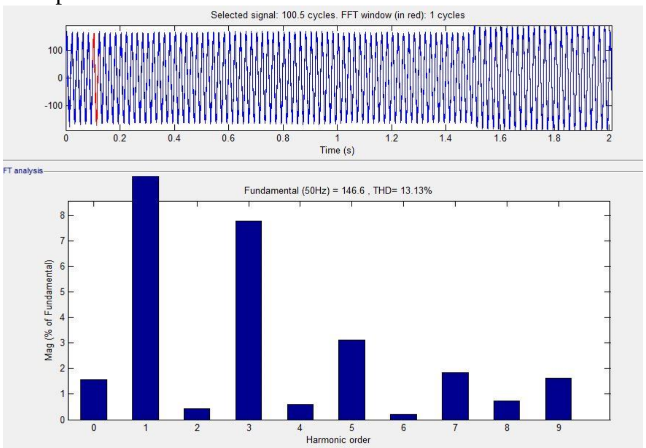

Fig. 7: THD analysis for before compensated graph

The figure is showing the THD analysis for the waveform before it is being compensated and we can see the amount of harmonic contents which is around 13%. The fundamental being 146.6HZ. The same harmonic content has to be reduced, that's what the initial aim of the project was. So next is when the compensator is applied how much THD we are getting will be shown by doing the same analysis.

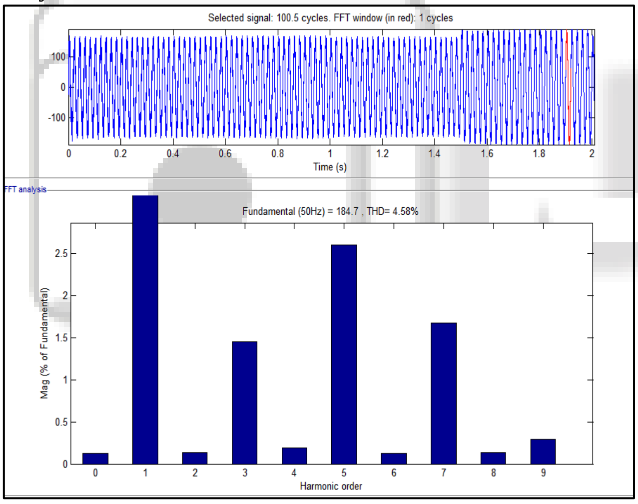

Fig. 8: THD analysis after compensated graph

So we can distinguish the difference easily from the two graphs that after applying with the compensation the content of the harmonic is considerably reduced to around 4% and which lessen by more than 50%. This shows the effectiveness of the project and work carried out though some more enhancement needs to be done as the remaining content of harmonics is also not desirable as it will degrade the quality of power if our waveform goes out of shape.

So from the graphs drawn and whatever study we have finished is finally at the end of the day it is giving us quite a good result as we expected though not the exact one, but still we are happy with the output which we got for all the cases and I hope in the future also it will be helpful for everyone if a product based on the design comes into the market and all can have a better quality power as in return.

VI. CONCLUSION

So the dual unified power quality conditioner has been studied here with the controller being adaptive neural fuzzy based and the results are plotted for various cases of power quality like voltage sag and swell and also the harmonic content of the waveform is also measured with the reduction of the harmonic content is observed. The advantage of using the neural based controller can be seen in the response time of the compensated output waveform. The PI controlled waveform takes a little time initially to reach the desired level of output whereas the neural based the response is quite faster. The further study on the other various power quality issues need to be conducted and the dual unified power quality conditioner could be a real asset in mitigating various kinds of power quality issues and to bring stability in the system.

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