ANFIS Control of Smart Transformer for Distribution Systems

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Abstract— Nowadays as we know most of the loads that we are using will inject harmonics into the system. For removing the harmonics content, in this project we are using two feeders in a distribution system in which a normal transformers are used in both the feeders. In this case we are going to replace one of the feeder transformer by a smart transformer, which consists of three different stages that is rectifier, buck converter and inverter. Rectifier converts ac to dc and buck converter used for stepping down dc and inverter used for dc to ac. So, the operation of the smart transformer is same as normal transformer. But, rectifier consists of IGBT valves, it needs pulses for operation. For generating the pulses we are using ANFIS controller. In that two currents will be taken from both the feeders and it is compared to the reference current and depending on the changes in the current value the pulse will be generated. The current changes means if any harmonics present in the system means it affects the current values so the change value is taken for pulse generation so that the amount of change in current is maintained by the rectifier by taking the pulses given by the ANFIS controller. Thus, the harmonics, unbalance and other things will be mitigated.

Key words: Smart Transformer for Distribution Systems, ANFIS Control

I. Introduction

Electricity is one of the major equity in nowadays society and in that, the transformers are one of the main component of the whole system. Transformers are used to send power to distant locations, which is with higher efficiency. For the purpose of distribution voltage is brought down to lower value and then sent to the consumers. Transformers are used from many years to increase or decrease the level voltage. And also this has efficiency and low pricing. But, renewable energy is connected to the system so, the new designs has to be made to work properly.

PE devices have offered the improvement in the quality of power for the networks. Such networks are example of adaptable transmission of power, VAR and condensers and so on. The ST, is another kind of transformer that acknowledges voltage change and power quality improvements by itself. The ST is reasonable for the utilization in the networks that contain renewable sources, batteries and other loads. For this purpose, transformers is taken out and a new type of transformer is added. It is known as smart transformer. There are 3 steps in the new type transformer. First input ac to dc conversion and then dc from high level to low, dc is converted back to ac. But problem is from dc to dc converter because it generates switching harm for example, stray inductance, reversing of diode. The best method of circuit will be DAB. In actuality, DAB based confinement stage for ST has as of now been worked for many kilowatts. Voltage from transformer and the auxiliary should be same in case of the best execution. From that we can achieve negligible tension in the gadgets and also switching is soft so that the efficiency can be increased. Notwithstanding giving points of interest except the change in voltage the new smart transformer can give few extra advantages like balanced waves, same phase angle produces best pf. It also manages the transients and also provides the access to connect DER to secondary of transformer.

The flow of power is from only one side that is from generating companies to the consumers. These days a large portion of the European nations have begun to change the power market. Keeping in mind that to improve the power market, (DSOs) will work on the power market straightforwardly and without the control of the government. This situation needs the connection of RES. The new topology is created by doing research for the purpose of cost and efficiency of various phases in ST also control ability of power, increased internal failure withstand capacity, and so on. And many upgrades have been accomplished. As of late, power system has many oppositions, for example, harmonics, quality of power, problems in renewables etc, all of these increase the demand of transformer. Older transformer is less costly than new smart transformer. Because of the cost it must give additional advantages and also the applications. In any case, elements in ST, energy circulation networks are not investigated. Consider an equal single line graph of a traditional CPT comprising 2 feeders of downtown area. 2 feeders will be having 2 different transformer for voltage stepping down which will be connected to the secondary network. Because of the way of the loads, problems will appear those are less pf, unbalance in waves and changes in the wave level etc.

Problems in quality of energy we are getting is a vital subject recently. The high level of technological improvements in industries, commercial and private devices, the users for electricity is rapidly increasing also increase in nonlinear loads in the distribution systems will increase power electronic devices. Moreover, the association of DER (i.e., distributed generation, storage devices) is raising new difficulties. Case in point, the generation of solar and other energy is more and it makes the power passing from consumers to grid. While passing it goes through the transformers. In a future distribution network, one of the transformer in one of the feeder is removed and ST will be added in place of that. The performance of ST in first feeder fundamentally enhances and gives points of interest like unbalanced sinusoidal currents, unbalanced voltages, no impact on the grid side. Be that as it may, the second feeder doesn't have any devices for compensating. Thus, above said problems will exist. Taking all the problems said, ST will be used for overcoming that problems and improve the electrical network. The results shown here that by what method ST provides compensation in power distribution.

II. METHODOLOGY

A. *Explanation*

Normal distribution transformers are used for increasing the voltage from the generation and also reduces for distribution. These transformers are used from 10 decades. It is the heart of the power systems. It is very less cost, higher efficiency. But, increase in generation by renewable energy needs new technology to connect to the grid. In this paper smart transformer is designed and is used to replacement of the transformers. The ST is a simple PE device transformer which has 3 steps in converting the voltage to other level. Which consists rectifier, buck converter and then inverter. In which, rectifier is used to convert incoming ac to dc and the buck is used to convert dc to low level dc and then inverter for dc to ac. So, the technique is different but the operation is same as the old transformer as said.

The ST can provide balanced voltages and currents and then the unity pf, also removes the sag, swell and transients etc. and also it has the option for connecting the DER to the secondary side of ST, so that the both directions can be achieved for improving the grid. In this project, two feeder system is used with two normal old transformers shown in fig. 4.1 but one of the transformer is replaced by the ST as shown in fig. 4.2. The ST connected to feeder 1 so feeder 1 does not require any devices to maintain quality of the power as explained. But feeder 2 has many more problems as it is connected by the nonlinear load.

But, ST present in the feeder 1 also maintains the quality of the feeder 2 by providing suitable help. That is, ST consists of rectifier and its with IGBT switches, for gate we need to supply pulses, that pulses is generated by the control loop.

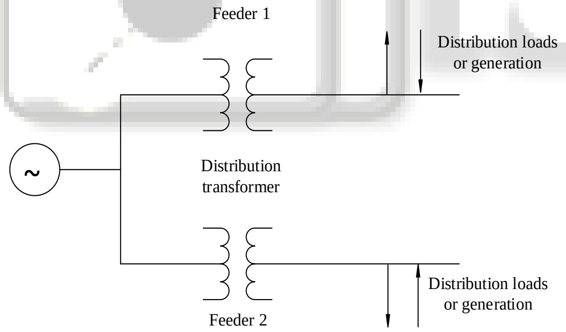

Fig. 1: Normal distribution system

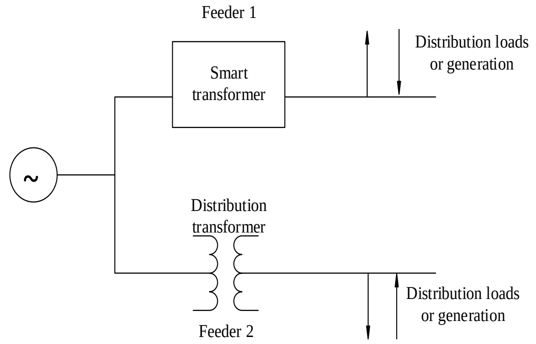

Fig. 2: Proposed distributed system

We know that any problems like harmonics in feeder 2 reflect to the grid so, grid is having problems. Here, we are taking the values of the current from feeder 1 and 2 and compared by a reference signal or current and the small difference in current value is given to the PWM converter to generate the gate pulses for triggering of the IGBT. Thus, IGBT valves conduct and rectifier operation proceeds. The output of the average value of the current from both feeders. Thus, any change in current will be maintained by the IGBT. The rectifier uses rectifier with neutral point clamped system which consists of 12 IGBT switches so 12 gate pulses are generated. The ST can be used in the medium voltage distribution system for feeder distribution purposes to achieve greater efficiency in the distribution system. The current calculation of feeder 1 and 2 are explained below.

III. MODIFICATION

In this system instead of PI controller ANFIS controller is used for controlling of the Pload1 and Pload in feeder1 for calculating reference currents. Also, ANFIS controller reduces the harmonics in the system. The ANFIS is a type of a fuzzy controller, it comes under sugeno type. Further explanation is explained below.

A. *Fuzzy Controller*

The method of fuzzy module is a system for processing with words which can manage imprecision and granularity. The human mind can translate and prepare uncertain and deficient sensor data which are gotten from the discerning organs. Similarly the fuzzy set hypothesis can likewise give a precise way to deal with manage such data semantically. It can likewise perform numerical calculation by utilizing participation capacity for the stipulated linguistic names.

B. *Fuzzy Interference Systems*

The Fuzzy interference system (FIS) depends on the ideas of fuzzy set hypothesis, fuzzy if-then standards and fuzzy thinking. The encircling of the fuzzy if-then guidelines frames the key segment in FIS. FIS is an exceptionally mainstream strategy and has been generally connected in various fields like information grouping, programmed control, master framework, basic leadership, mechanical autonomy, time arrangement examination, design order, network recognizable proof and so forth. The fundamental structure of a fuzzy derivation framework comprises of three central parts viz a standard base including the chose fuzzy guidelines, a database characterizing the participation elements of the fuzzy principles, and a thinking component which performs a fuzzy thinking deduction concerning the tenets in order to determine a sensible output or conclusion.

C. *FIS Analysis*

The analysis of FIS is carried out by steps explained below,

- Fuzzification: the fuzzy rules are converted into fuzzy sets, these are from linguistic variables and the degree of the rules depends upon the membership functions. This method of rules is done by the crisp input and it is known as fuzzification.
- Aggregation: After the degree of rules calculated the inputs are combined by AND, OR gates and the rules must be created must be suitable for the smoothness and differentiability.
- Activation: in this output rules are calculated.
- Accumulation: the activated output rules are combined together to form the output of the fuzzy system.
- Defuzzification: if any crisp data is required then the system must be defuzzified by many methods.

IV. SIMULATION MODEL

The simulation model of the proposed system is modelled using MATLAB. The simulation work is divided into two categories. One part consists of construction of feeder system and second part is sub system which is used to generate gate pulses. The modelled systems are shown in this section.

There are 3 conditions in this simulation,

- Without control loop.
- With control loop.
- Increased load with control loop.

All the 3 conditions diagrams shown below and also feeder 1, feeder 2 current calculation and pulses generation loop figures shown.

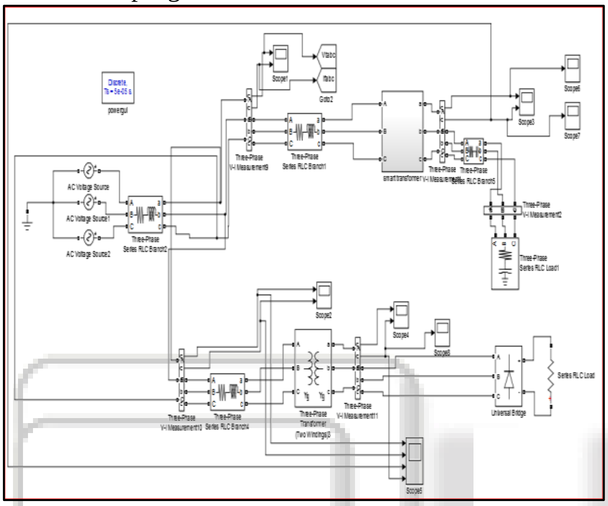

Fig. 3: MATLAB model of distribution system

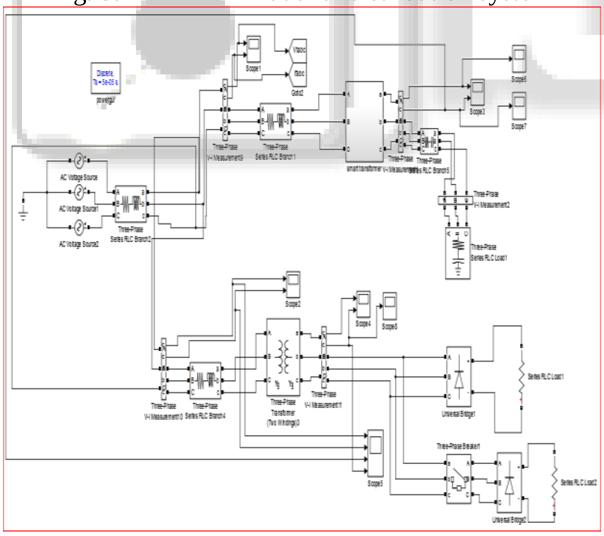

Fig. 4: MATLAB model system with increased load after 1second

Fig. 3 shows the proposed diagrams of the simulation of with and without control, both the feeders are given a load but feeder 2 is given by non linear load. In fig. 4 system, an extra load is added to feeder 2 to know how the system reacts with the increased load. A load is added through a breaker, the breaker is closed after 1 second and both the outputs of the system is analysed. The scopes are added to measure the values of current and voltage of all the feeders and grid and load side values. The measured values graphs are obtained from the scope and analysed. For the loads in this system, a resistive load is used in feeder 1 and universal bridge load is used because of the non linear load. It will introduce the harmonics in to the grid. So that the smart transformer will limit the harmonics.

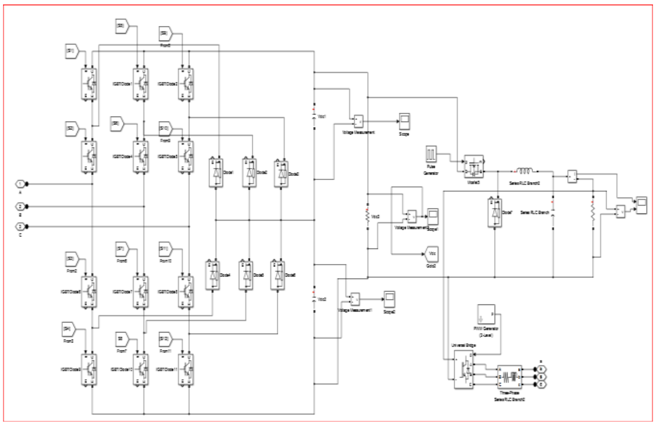

Fig. 5: MATLAB model of smart transformer

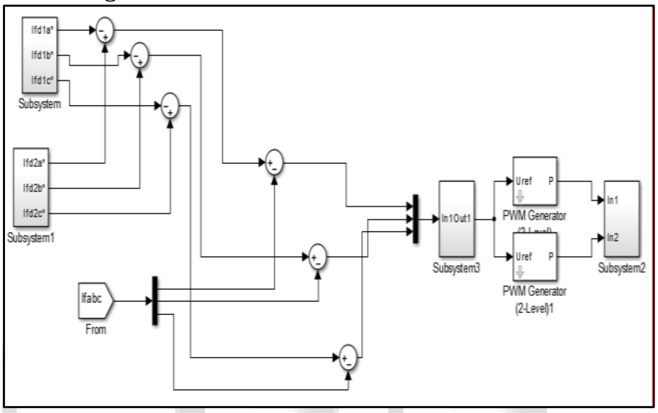

Fig. 6: MATLAB model of control loop to generate pulses for IGBT valves

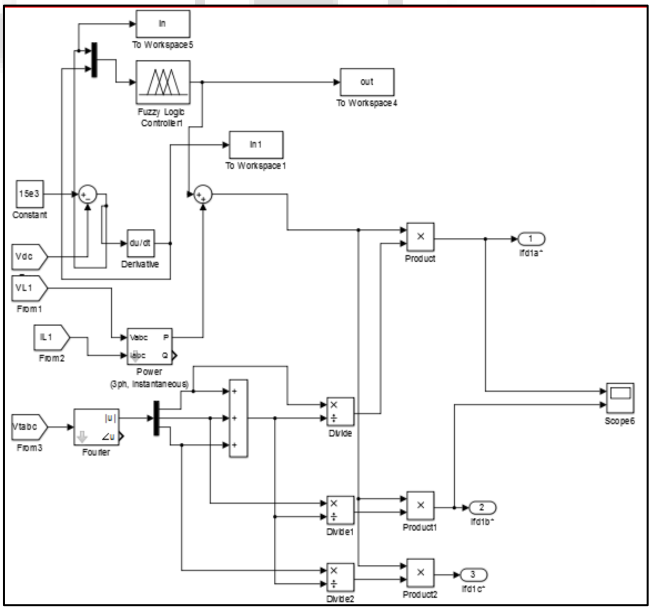

Fig. 7: MATLAB model of calculating feeder 1 current with ANFIS controller

Fig. 5 is the inside of the smart transformer device, which is having 3 stages converter, buck converter and inverter. So, the input is ac and out coming is step down ac. Same as transformer but its with PE devices. Fig. 6 is control loop to generate gate pulses for rectifier IGBT valves. Gate pulses generated by comparing reference current with calculated current. Thus, using PWM technique gate pulses are generated. Fig. 7 shows how ANFIS controller is working to calculate the current value from feeder 1.

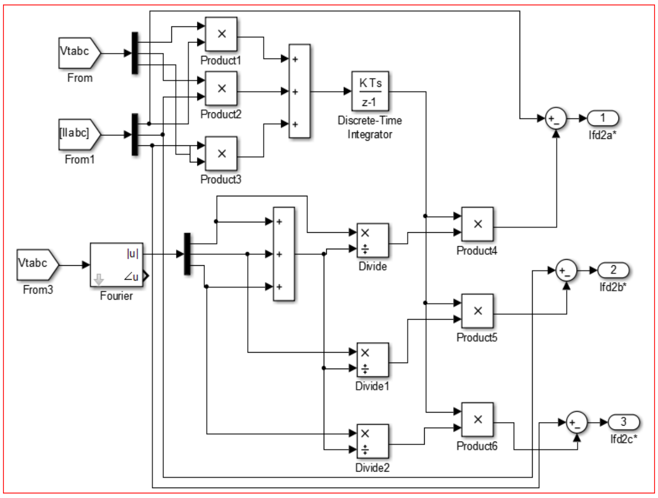

Fig. 8: MATLAB model for current calculation in feeder 2

V. RESULTS AND DISCUSSION

A. *Case 1: Open Loop*

Fig. 9, 7.10, 11 shows the output waveforms of the open loop system. Open loop means, there is controller for generating pulses to the IGBT. PWM generator is directly connected to the converter with normal gate pulses. Thus the current and voltage waveforms are obtained shown from the grid, feeder1 and feeder2. From grid current and voltage we can say that both are not in phase. Hence, power factor is not unity and also in the feeder currents harmonics is more.

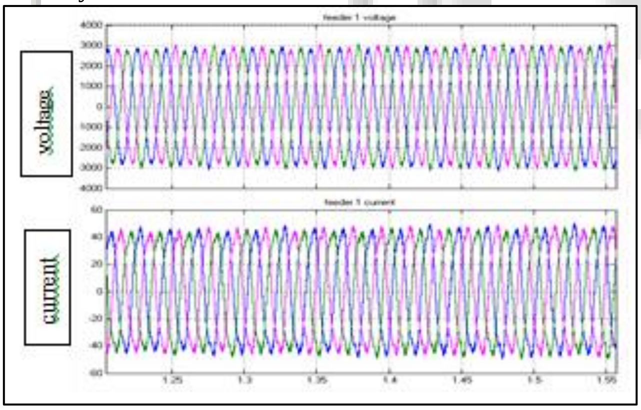

Fig. 9: feeder 1 voltage and current v/s time waveforms

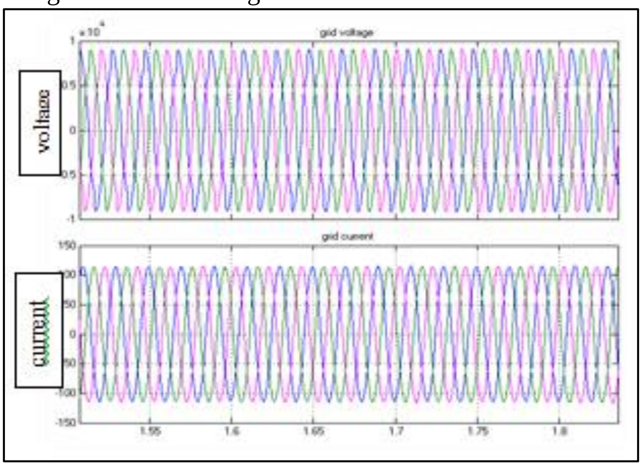

Fig. 10: feeder 2 voltage and current v/s time waveforms

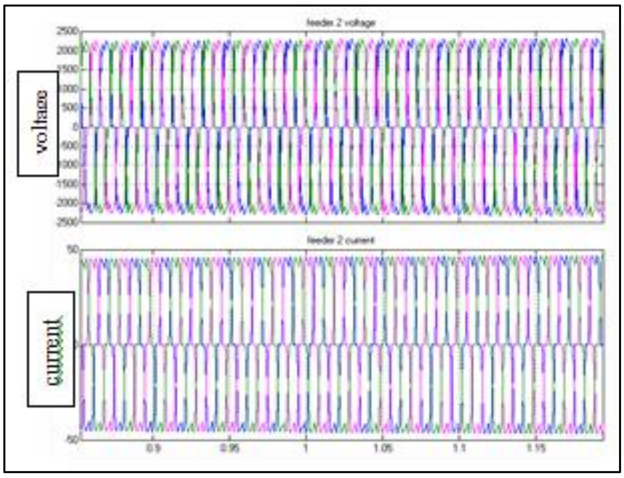

Fig. 11: grid voltage and current v/s time waveforms

B. *Case 2.1: PI Controlled*

Fig 12, 13, 14 shows the output wave form of the system. Here we can say that grid voltage and current are in phase and also harmonics level is reduced compared to the open loop system.

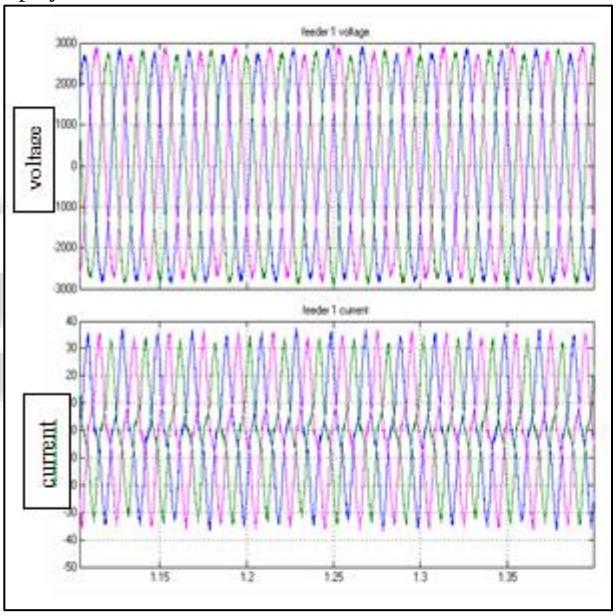

Fig. 12: feeder 1 voltage and current v/s time waveforms

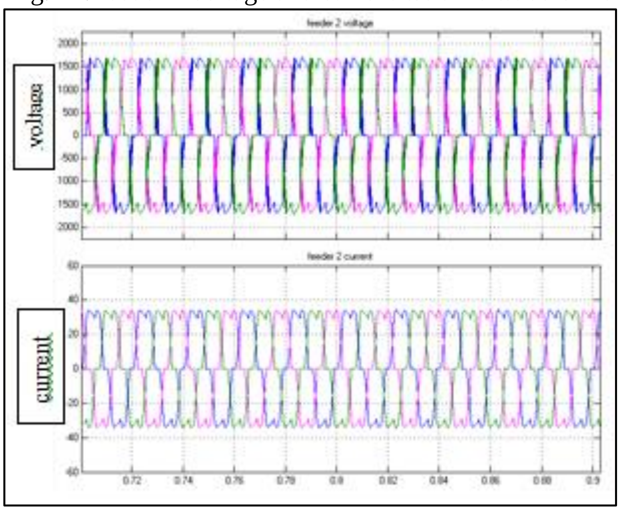

Fig. 13: feeder 2 voltage and current v/s time waveforms

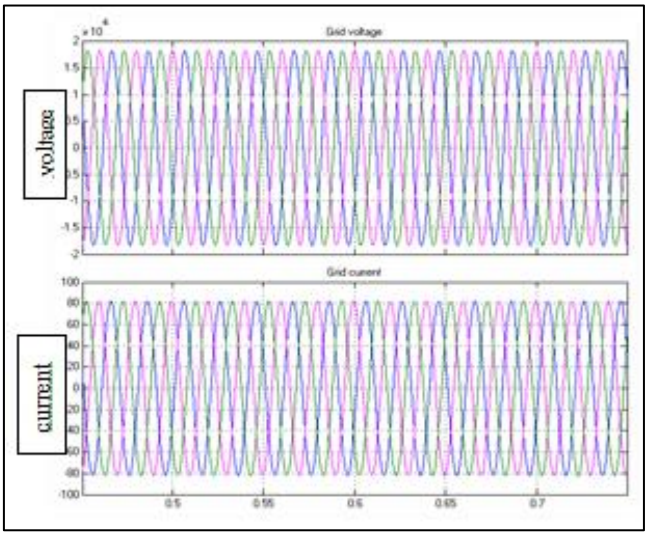

Fig. 14: grid voltage and current v/s time waveforms

C. Case 2.2: PI controlled with increased load

Fig. 15, 16, 17 shows the output of the increased load case. We can see that current in feeder 2 is increased suddenly after 1 sec thus, the voltage reduces. Same as in the grid but a small change in current and voltage because of feeder 1 load.

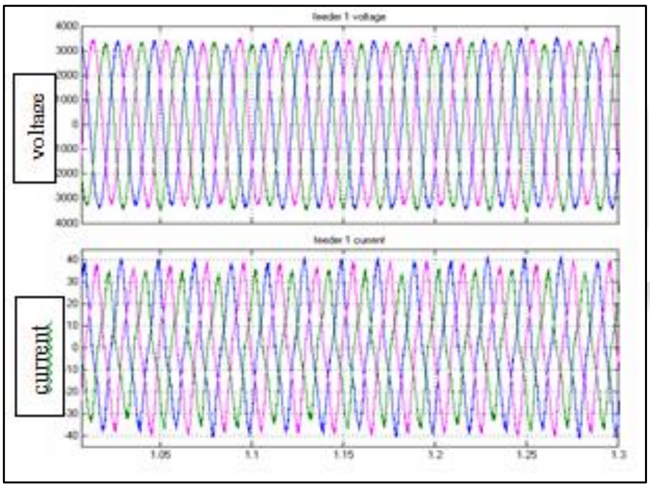

Fig. 15: feeder 1 voltage and current v/s time waveforms

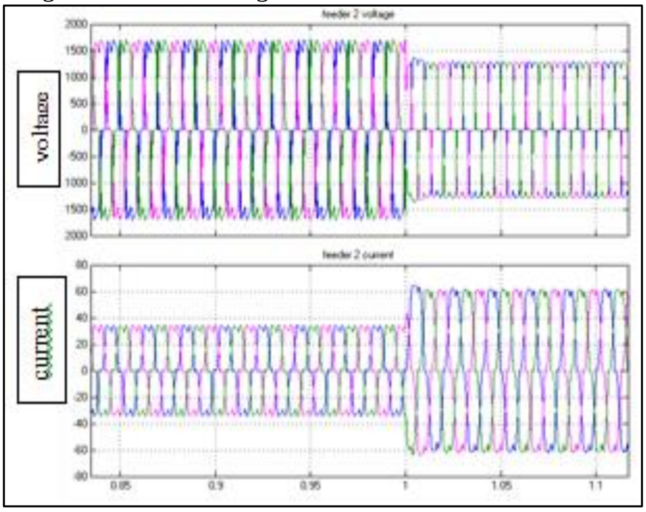

Fig. 16: feeder 2 voltage and current v/s time waveforms

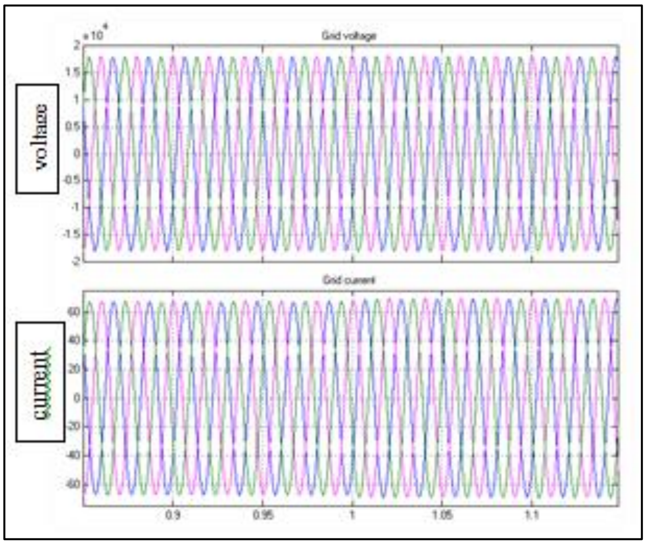

Fig. 17: grid voltage and current v/s time waveforms

D. Case 3.1: ANFIS controlled

The below Fig 18, 19, 20 shows the output waveform of the system. Here the grid voltage and current are in phase and also harmonics level reduced compared to PI controlled system.

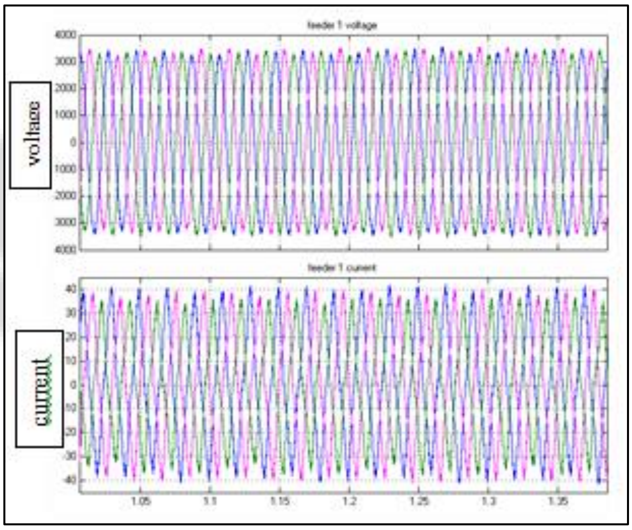

Fig. 18: feeder 1 voltage and current v/s time waveforms

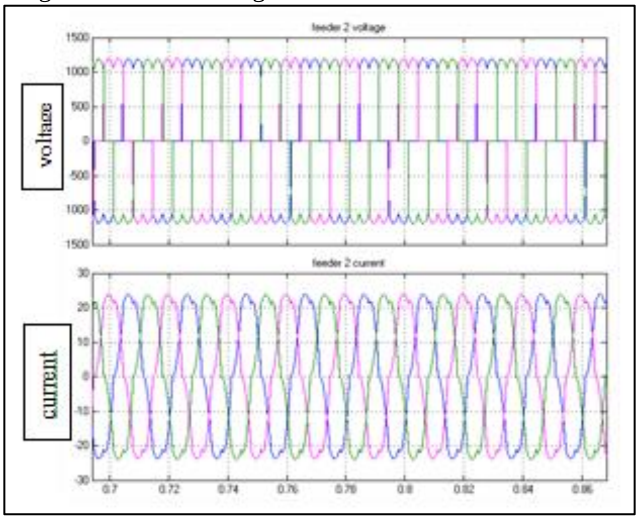

Fig. 19: feeder 2 voltage and current v/s time waveforms

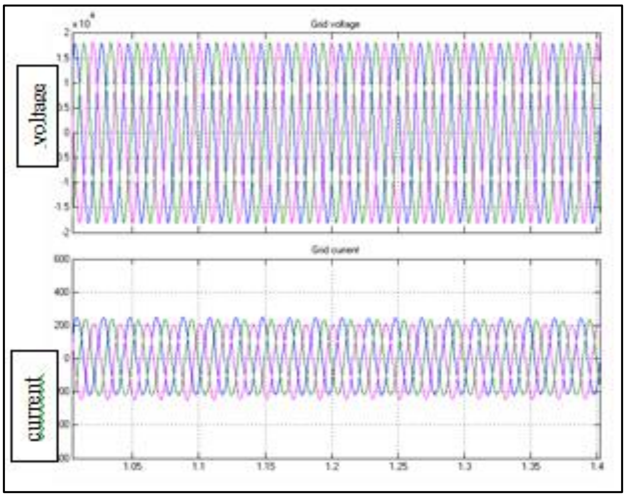

Fig. 20: grid voltage and current v/s time waveforms

D. Case 3.2: ANFIS Controlled with increased Load

The below Fig. 21, 22, 23 shows the increased load of the ANFIS controlled system. In this we can see the current and voltage changes in the feeder 2 and the grid. This is due to the increased load at feeder 2 after 1 second.

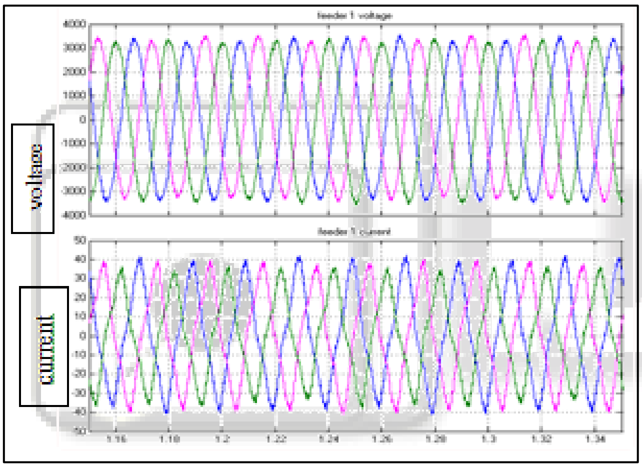

Fig. 21: feeder 1 Voltage and current v/s time waveforms

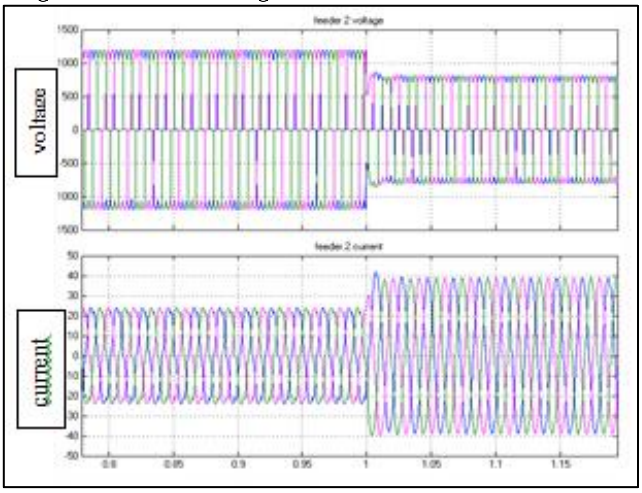

Fig. 22: feeder 2 voltage and current v/s time waveforms

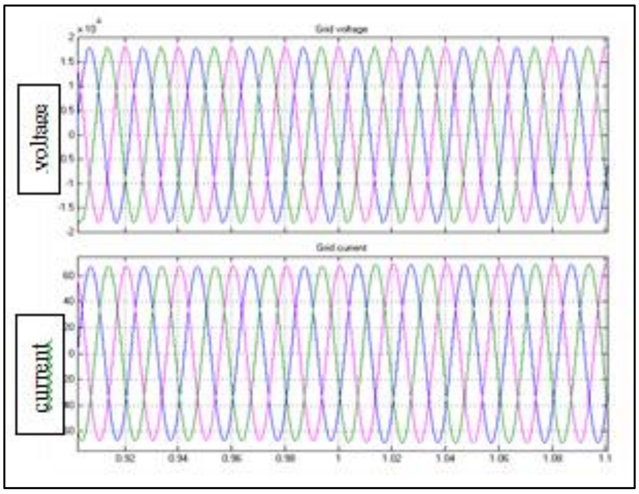

Fig. 23: Grid Voltage and current v/s time waveforms

E. THD Calculation

THD (total harmonic distortion) calculation is used to measure the percentage of harmonics in a particular wave. Here, in this the difference between the PI and ANFIS controller shown. From this we can say that by using ANFIS controller, harmonics is reduced.

Parameters	PI Controlled	ANFIS Controlled
Feeder1 Current	28.58%	15.59%
Feeder 2 Current	19.34%	9.58%
Grid Current	1.98%	0.68%

Table 1: THD values

VI. CONCLUSION

In this paper, future distribution of the power system network from the substation to the consumers with 2 feeders is taken into account. With one of the normal transformer is removed and ST is inserted in one feeder. The ST can provide the loads for its feeder line and also it manages the loads in the normal transformer feeder. This method of using ST excludes the use of power quality devices in the network. Such as, STATCOM, capacitors for pf correction etc. in the other feeder. This type of system makes the ST attractive and less costly.

REFERENCES

[1] C. Kumar and M. Liserre, “Operation and control of smart transformer for improving performance of medium voltage power distribution system,” in 2015 IEEE 6th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), 2015, pp. 1–6.

[2] S. S. Ahammad, T. M. Prakash, and P. Murali, “Harmonics compensation in a Grid-Connected Single-Phase PV Inverter.”

[3] S. Bifaretti, P. Zanchetta, A. Watson, L. Tarisciotti, and J. C. Clare, “Advanced Power Electronic Conversion and Control System for Universal and Flexible Power Management,” IEEE Trans. Smart Grid, vol. 2, no. 2, pp. 231–243, Jun. 2011.

[4] X. She, R. Burgos, G. Wang, F. Wang, and A. Q. Huang, “Review of solid state transformer in the distribution system: From components to field application,” in 2012 IEEE Energy Conversion

Congress and Exposition (ECCE), 2012, pp. 4077–4084.
[5] S. Alepuz, F. González, J. Martín-Arnedo, and J. A. Martínez, "Solid state transformer with low-voltage ride-through and current unbalance management capabilities," in IECON 2013 - 39th Annual Conference of the IEEE Industrial Electronics Society, 2013, pp. 1278–1283.
[6] R. Peña-Alzola, G. Gohil, L. Mathe, M. Liserre, and F. Blaabjerg, "Review of modular power converters solutions for smart transformer in distribution system," in 2013 IEEE Energy Conversion Congress and Exposition, 2013, pp. 380–387.
[7] P. Yong, M. Hong, Z. C. Bi, and Z. C. Feng, "A solid-state transformer with controllable input power factor and output voltage," in 2014 International Conference on Power System Technology (POWERCON), 2014, pp. 2940–2944.
[8] T. Besselmann, A. Mester, and D. Dujic, "Power Electronic Traction Transformer: Efficiency Improvements Under Light-Load Conditions," IEEE Trans. Power Electron., vol. 29, no. 8, pp. 3971–3981, Aug. 2014.
[9] G. D. Carne, M. Liserre, K. Christakou, and M. Paolone, "Integrated voltage control and line congestion management in Active Distribution Networks by means of smart transformers," in 2014 IEEE 23rd International Symposium on Industrial Electronics (ISIE), 2014, pp. 2613–2619.
[10] X. She, A. Q. Huang, and R. Burgos, "Review of Solid-State Transformer Technologies and Their Application in Power Distribution Systems," IEEE J. Emerg. Sel. Top. Power Electron., vol. 1, no. 3, pp. 186–198, Sep. 2013.
[11] G. G. Oggier and M. Ordonez, "High efficiency switching sequence and enhanced dynamic regulation for DAB converters in solid-state transformers," in 2014 IEEE Applied Power Electronics Conference and Exposition - APEC 2014, 2014, pp. 326–333.

