Modern Methodology Introducing for Three Layers Intelligent Universal Transformers in Advanced Distribution Automation Equipping Pi Voltage and Current Source Controllers

Maryam Sadeghi and Majid Gholami

***Abstract*—Intelligent Universal Intelligent Universal Transformer (IUT) is a multifunctional transformer accounts as an Intelligent Electronic Devices for the tomorrows Advanced Distribution Automation (ADA). IUT is a HV power electronic base transformer with full monitoring and control ability is introduced instead of traditional current transformer. HV oil free transformer utilization in IUT results in size and weight reduction, oil pollution elimination and maintenance free equipment. PI current source controller senses the input current of IUT and holds it in phase with input voltage to prevent harmonic distortion. In output stage, PI voltage source controllers regulate the output voltages result in favourable desired outputs and improve the performances under load and source disturbances. Automatic sag correction, DC voltage option, real time voltage regulation, reliable diverse power as 400Hz service, three-phase power from a single phase line, Harmonic Filtering, Flicker mitigation, options for energy storage and dynamic system monitoring are the resulting benefits of proposed control fashion and three layers IUT model.**

***Index Terms*—ADA, IUT, IED, DER**

I. Introduction

ADA describes a flexible distribution automation contributed with the Advanced and full automated control devices to perform exchanging both the electrical energy and information among the participants and system components rather than the Traditional Distribution system which only concerned to distribute the energy to end-users [1], [3], [7], [14].

ADA will bring up a new approach and methodology with a major revolution in control and managing in distribution automation systems. Dynamic system monitoring with a fully controllable functions are the benefits which will arise from the concept of open communication architecture.

Re developed electrical architecture and open communication architecture, facilitate exchanging Data and information in a dynamic manner against the traditional static fashion. These two synergistically empowered each other and will comprise the future of distribution Automation system.

An interoperable network of intelligent electronic devices with flexible and redeveloped electrical architecture in nature comprise the strategic manner leads to improve the functionality, reliability, performance and power quality of system.

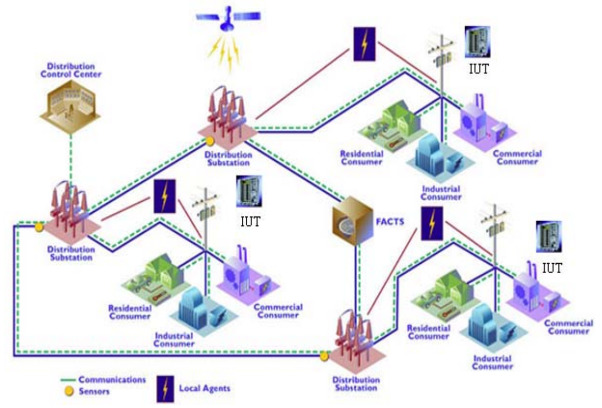

Fig. 1. Conceptual view of ADA using IUT in future distribution Automation systems [1]

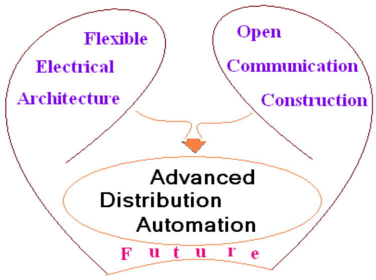

Fig. 2. ADA topology comprising the flexible electrical architecture among with an open communication architecture empowered each other to enhance the synergy

ADA is the state of art with flexible electrical network of component and open communication architecture comprises the Future Distribution System. ADA debates new modern technologies evolving Distributed Energy Resources (DER), Intelligent Electronic Devices (IED), new sensors and new power-electronic appliances. In lieu of traditional distribution transformers, Intelligent Universal Transformer is one of these new applications with multi-functional construction in nature [2], [4], [8]-[12], [15]. Different topologies, design methods and applications are described for Intelligent Universal Transformers [16]-[19], [13], [6]. IUT concept and topology, STGO and modern IGBT are introduced in the next section. Section III elucidates the control strategy. section IV evolve the simulation of three layers IUT topology based on 7 main individual blocks with PI current source and PI voltage source controllers in input-output stages. In the last section conclusion with presenting the prospective features have been shown.

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II. Intelligent Universal Transformer Concept and Topology

A. IUT Concept

The new modern power electronic technologies supported creation of the new advanced technology described here as Intelligent Universal transformer (IUT). IUT is a basic resource and a key point in ADA construction for the next near future. It is a high voltage low current power electronic base transformer will be raised instead of the traditional distribution transformers with the major benefits that comes from it: New service availability like automatic sag correction, DC voltage option, voltage regulation in real time operation, reliable diverse power as 400Hz service, availability of three-phase power from a single phase line, Harmonic Filtering, Flicker mitigation, storage energy options and dynamic system monitoring. New construction as high voltage, low current solid-State devices especially SGTO and high frequency transformer leads reduction in IUT physical dimensions and weight. Using HV oil free transformers eliminate oil pollution and maintenance free equipment. The word intelligent comes from the control ability in solid state converters in input/output stages.

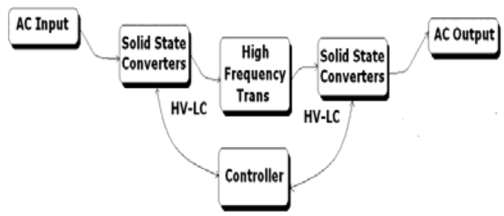


Fig. 3. ADA topology IUT construction comprising the "High voltage", "Low current" power electronic base transformer

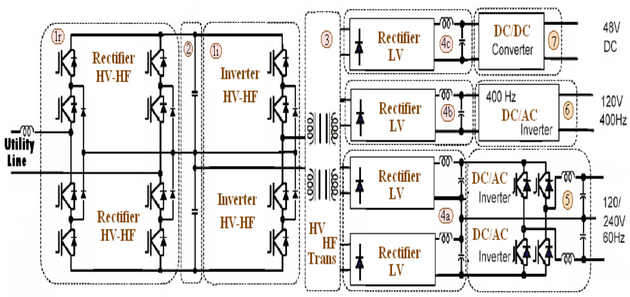


Fig. 4. IUT Circuit Topology based on 7 main individual blocks

B. IUT Topology

IUT topology is based on 7 main individual blocks comprising the power electronic equipment and high frequency transformer. Fig 4 demonstrates the IUT Circuit Topology based on 7 main individual blocks. At the first stage we are deal with the rectifier and inverter. A multilevel rectifier (1r) in the first stage rectifies the AC input voltage at the 50-60 HZ frequency. Multilevel Inverter (1i), produce high frequency high voltage square wave. Second stage is a DC bus capacitors (2), enrolled to makes the DC voltage from the rectified input. Next stage is high frequency transformer (3), which is so small compare with the traditional transformer and the task is to pass the high frequency square wave with the ratio of 1:1 and isolating two sides from each other. Next stage comprises the rectifiers and filters (4), yield to DC outputs. Main inverter with 120/240-V 60-Hz output (5) is the fifth stage.In this topology, an auxiliary inverter is designed for 400-Hz output (5). The last stage is DC/DC converter (6), producing 48-Vdc output. As described, IUT has the capability to evolve three different kinds of outputs (stage 5, 6 and 7) which makes the IUT defined as a critical point in the ADA conceptual and user benefits advantages.

C. SGTO & Modern IGBT

New modern HV power electronic technologies have been raised by IUT. Advanced solid-state switching technologies based on Super Gate Turn-Off Thyristors (SGTO) or modern IGBT are required for the new topology of transformers [5]. Advantages are high input impedance, high junction temperature, on-state drop reduction, very high "off" resistance, reduction in conduction drop, rapid turn-on and off switching, withstanding in high voltage and current condition, high current density, ability to work on high temperature and high frequency, high power capability.

III. Control Strategy

Control strategy is based on the two fundamental concepts: controlling the burning angle start point and integrating the power from the start to the stop point. These two will be happened in two strategic points. First in the input stage (rectifier unit), yields to constant voltage from the sinusoidal input voltage and eliminating the harmonic distortion in contrast to the primary stage. As IUT is connected directly to the grid in primary stage, to prevent the harmonic distortion, input current should be sinusoidal and in phase with the input voltage. In this regard the Input current is sensed and controlled by a current source controller. The other controller is in the output stage in the DC/AC converter (fig 5).

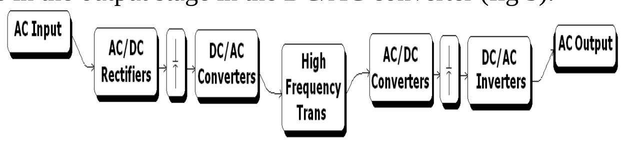


Fig. 5. IUT Main component diagram

This leads to constant output in spite of different loads. Each inverter in the output stage will be controlled by a voltage source controller.

IV. Simulation in Mathlab

Fig. 6 demonstrates IUT with three layers topology circuit diagram and control units. It is connected directly to the 500V, 3 phase sinusoidal input voltage.

IUT outputs are 3 phase sinusoidal and 240V DC. In the first stage (input section) IGBT rectifiers composed of three bridge arms 6 rectifiers, rectify and convert the input voltage to DC. The voltage keeps constant by PI controller and controlled by synchronized 6 pulse generator. The IGBT Inverters convert the DC voltage to High frequency square wave that pass through the High frequency transformer. Transformer outputs voltages are rectified among four AC/DC converters base on four IGBT rectifiers have duty to produce four DC buses. DC voltages will hold constant by four voltage regulators in output stage. The first 240V DC bus will be converted to 48V DC by PWM DC/DC converter.

Two other 240V DC buses have been converted to two 240V AC 60 HZ outputs by two DC/AC inverters base on two arms IGBT inverters.The last 240V DC bus becomes 120V AC 400 HZ by DC/AC converter.

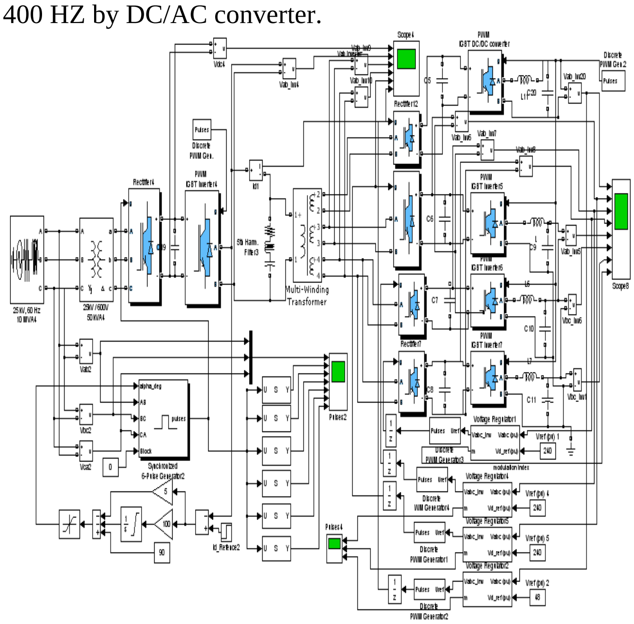


Fig. 6. IUT three layers topology (48V DC output, 120V AC 400 HZ, two 240V AC 60 HZ) with voltage source PI controller and current source PI controller in input output stages

In the input stage, the current source controller composed of a PI controller, “Step time” module and up - down limiter, senses the output current of input IGBT rectifier, compares this to “Step time” module with the initial value of 10 and final value of 25 by the step time of 0.04 second. It provides two definable levels at the step time. Then the PI controller gets the control role and limits the amplitude of input current of alpha degree in “synchronized 6 pulse generator” module by limiter. In the output stage, the voltage source controller composed of a PI controller and voltage regulator leads to constant output voltages, eliminates distortion in load disturbances. PI voltage source controller is shown in fig 7.

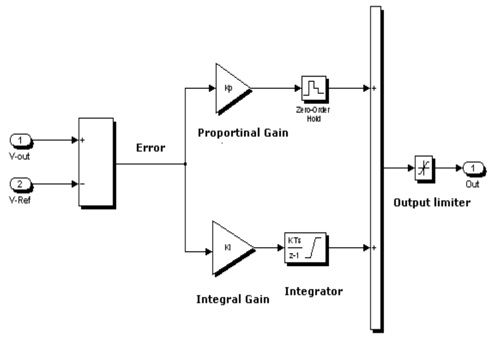
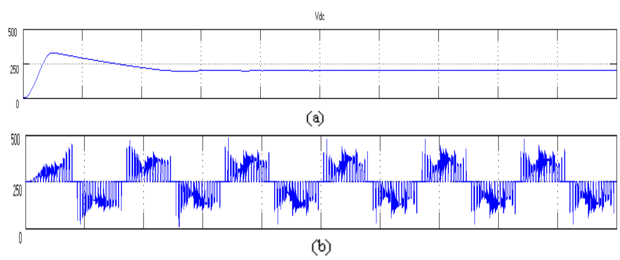


Fig. 7. IUT PI voltage source Regulator in output stage

This controller regulates the DC buses voltages and makes them constant during the disturbances occurred in time of load changes.



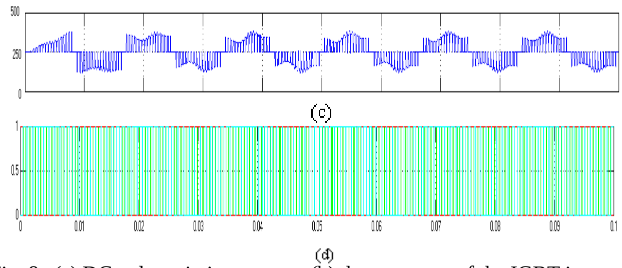


Fig. 8. (a) DC voltage in input stage, (b) three outputs of the IGBT inverters in DC/DC converters in the output stage of HF transformer, (c) input voltage in the input of transformer (d) alpha degree in voltage source controllers.

Simulation results are shown in fig 8, 9 and 10. In “Fig 8”, the first figure (a) illustrates the DC voltage in input stage. Voltage riches the steady state of 240V DC at 0.005 S. Fig (b) is IGBT inverters in DC/DC converters. The next figures (c) is the output of HF transformer of IGBT inverter in DC/DC converter which is passed from the HF transformer with a 1:1 ratio. Figure (d) is the alpha degrees from voltage source controllers.

Fig 9 demonstrates three phase input voltage (a) and alpha degrees from pulse generator for controlling the current in the input current source controller (b).

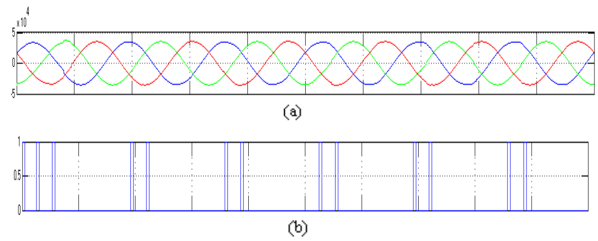
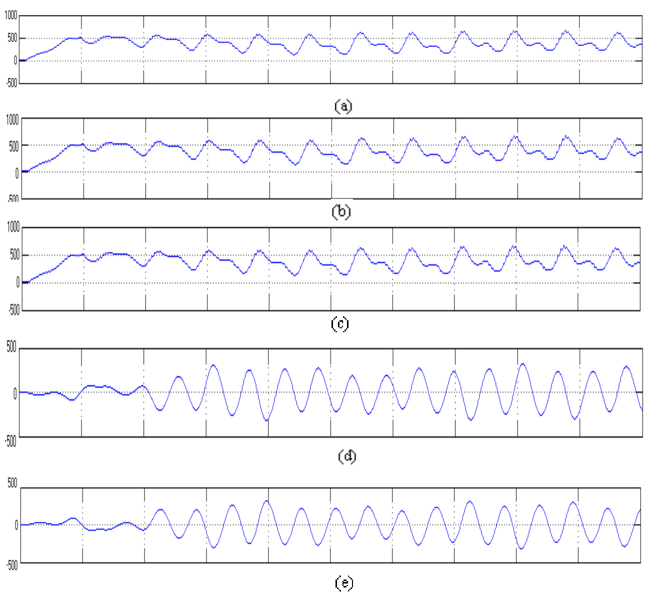


Fig. 9. (a) Three phase input voltage (b) alpha degree for rectifier in input stage

On Fig 10, three first figures comprise three rectified voltages in the three AC/DC converters (a, b, c, three outputs of IGBT rectifiers). In the next two figures (d, e) two 240V AC 60 HZ outputs voltages are shown. In the next figure (f), 48V DC output from PWM DC/DC converter is demonstrated. Modulation Index of the Output voltage source controller is shown in fig (g), the last figure is input current of transformer (h).



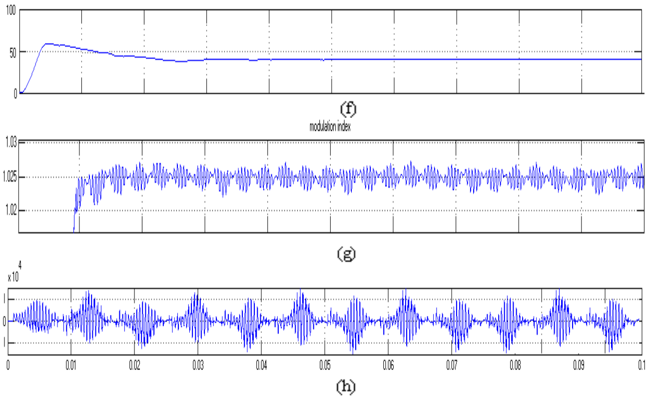


Fig. 10. (a-c) Three rectified voltages in the three AC/DC converters (three IGBT rectifiers outputs), (d) 240V AC 60 HZ output voltages phase 1, (e) 240V AC 60 HZ output voltages phase 2, (f) 48V DC output voltage , (g) modulation Index in voltage source controller output, (h) Input current of transformer

V. Conclusion

Infrastructure and modern new technology has been raised due to future distribution automation necessity deals with the Intelligent Electronic Devices and Distributed Energy Resources. In this regard, IUT is a key point for the Advanced Distribution Automation. IUT advantages have summarized in part II. In these simulation two PI controllers in both input and output stages guarantee the avoidance of system from input and output disturbances. Output DC voltage and three phase output voltage are available in this model due to conceptual IUT topology. Stability with a high reliability is a most advantages increase the efficiency of whole system operation. The future of IUT is directed towards full network functionality which especially will be presented in smart grid of future. Commercialization is a part of Innovation in power electronic technologies with integrated communications which will be stated in IUT forthcoming projects.

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