International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 141-155 www.ijaem.net ISSN: 2395-5252

Smart Transformer for Low Voltage Distribution System

B.Shiva Kumar, Harish Balaga …

Submitted: 01-01-2022 Revised: 05-01-2022 Accepted: 10-01-2022

ABSTRACT
As the population grows, so does the need for power transformers increases in a system. The production of low voltage has an impact on the electricity quality of customers that are linked to this grid. To prevent this issue, power transformer condition monitoring and diagnostics must be performed. Power electronic converters can provide this constant monitoring. Here, smart transformers system created may immediately decrease energy consumption by providing a steady, optimum power supply that feeds electrical equipment and improves quality, and utilising renewable energy sources such as solar and wind that can be linked in parallel with smart transformers. In consequence, high-tech microgrids, in particular smart grids, are used to link this technology to energy storage systems, communication networks and, in particular, smart transformer devices in current electrical systems. Supervising, reporting, and analysing every part of the grid enhance overall network performance by reducing losses and cost.
The intelligent transformer is a key element of the intelligent grid, consisting of an electronic device transformer coupled with efficient control and communication systems. This allows the electrical separation of the separate, low voltage and medium voltage grids. This enables two-way power streams and also enhances the electrical power quality of the system by filtering and minimizing disturbances, such as flickering, bumps and harmonics from one side of the intelligent transformer to the other.

Keywords: smart transformer ,rectifier, buck converter ,pv array, boost converter, inveter.

I. INTRODUCTION

Electricity is essential in our everyday lives; without it, it is impossible to exist in today's world. This thesis investigates the effect on the distribution network of scattered energy sources and the usage of various smart transformer topologies in order to solve the problems of this kind of generation. The concept of distributed generation in general, its advantages and disadvantages, and its impact in EPQ and distribution networks are covered in a brief introduction to the Electronic Energy Quality (EPQ) and transmission and distribution networks. Next will be a study of the microgrid and intelligent grid concepts and the intelligent transformer, its characteristics and the advantages of the network of distribution.

Displaying their features and effect on electricity networks will explore several smart Transformer Topologies, or gadgets which may be classified as smart Transformers. Technically, this thesis seeks to show how a conventional medium-voltage and lowervoltage connecting transformer may be converted into an intelligent instrument to regulate and react to changes made to the system via distributed generation (specially at voltage level).

Electricity may be produced using a variety of methods, including nonrenewable fuels, wind energy, nuclear energy, hydroelectric energy, and photovoltaic energy. Integrating various dispersed producing stations with an electric grid created numerous problems, including harmonics and bidirectional power flow in the system. To address this issue, a smart transformer is a viable option.

II. LITERATURE REVIEW

A detailed study on smart transformers prove to create a framework of power electronic converters. This causes progress in the field of smart transformers technology both in technological as well as economical. Here the choice of conversion can be done by using the power electronic converters, In[1], "Efficient constant current controller for PV solar power generated integrated with the grid."Proposed by the sweeka meshram which demonstrates the use of renewable energy sources in urban and suburban areas due to the generation of renewable energy sources. In this respect the efficient control system in a PV array power generation integrated into the grid with a power converter using MATLAB has been implemented.[1].

In the paper titled "Smart transformer-based hybrid LVAC and LVDC Interconnected Microgrid" by Chandan kumar, dwijasish das, Hrishikeshan VM it is a way of integrating nom- exhaustible sources into the grid makes it necessary to create a smart transformer. This scheme was implemented and verified by using PSCAD[2].

In the paper titled"Smart transformer for smart grid-intelligent framework
and techniques for power transformer asset management" by Huima, IEEE member, Tapan Saha, Chandima Ekanayake, Daniel martin. This paper describes a condition monitoring and assessment of power transformer knowing different types of faults in transformers [3].

In the paper titled"Coordinated frequency and voltage overload control of smart
transformers" by Giovanni de Carne, Giampaolo buticchi, Marco leisure, Panagiotis marinakis, Coastas vournas. This paper describes the regulation or maintenance of frequency and voltage control by using power electronic converters without derating the smart transformer i.e, reduces the current to protect against overloads at the local loads[4].

In the paper titled "A Review Of Smart transformers Architecture and Topologies" by Hiba Helali, Adel Bouallegue, Adel Kheder.This paper tells us the leads of smart transformers and existing topologies of smear transformers with compared to choose the well-performed one. Which are three state topologies[5].

In the paper titled "Investigation Of Smart transformer" by J.V.D Jayasuriya, M.M.H.C.N. Mahalaksha,P.J. Bindhuhewa, J.R.S.S. Kumara. This article sets the voltage control by use of a three-winding, intellegent transformer and controls the ST's secondary side voltage by injecting the voltage into the winding area. And limits and improvements were addressed in the development of prototypes[6].

In the paper titled"Voltage and current balancing in low and medium voltage grid employing smart transformer" by Giovanni de Carne, Giampaolo buticchi, Marco leisure, Frede blaabjerg, Yoon of Changwoo. In the event of uneven load circumstances of the LV grids, this article explains the separation of MV and LV grids. Significant improvements in voltage and control through the use of the technology for intelligent transformers

III. METHODOLOGY

This section covers the overall operation of a proposed system. This wing depicts the many words of the proposed system, allowing you to understand the purpose of each block.

Microgrid

Microgrid systems are electricity distribution systems consisting of integrated dispersed sources of energy, interconnected loads and storage systems which operate as a single regulated unit. This collection of electric sources and loads is usually linked to the central macrogrid and operates by the central control unit as a single unit controlled by a dispersed generation control system linked to each storage and distribution system. Microgrid power resources may include solar, wind, petrol and other energy sources of renewable or fossil fuels, fixed storage.

Including enhanced transient and stable State performance, enhanced market energy and strategy, increased management and environmental impact, higher reliability, efficiency, and power quality, and the presence of storage instruments, Microgrids deliver many different benefits to the distribution network. In addition, microgrids are composed of two buses:

- AC bus: where utility gird, ac loads and, in some cases, distributed sources as well are connected;
- DC bus: where distributed resources, dc loads, plug in devices and storage devices are connected. [22]

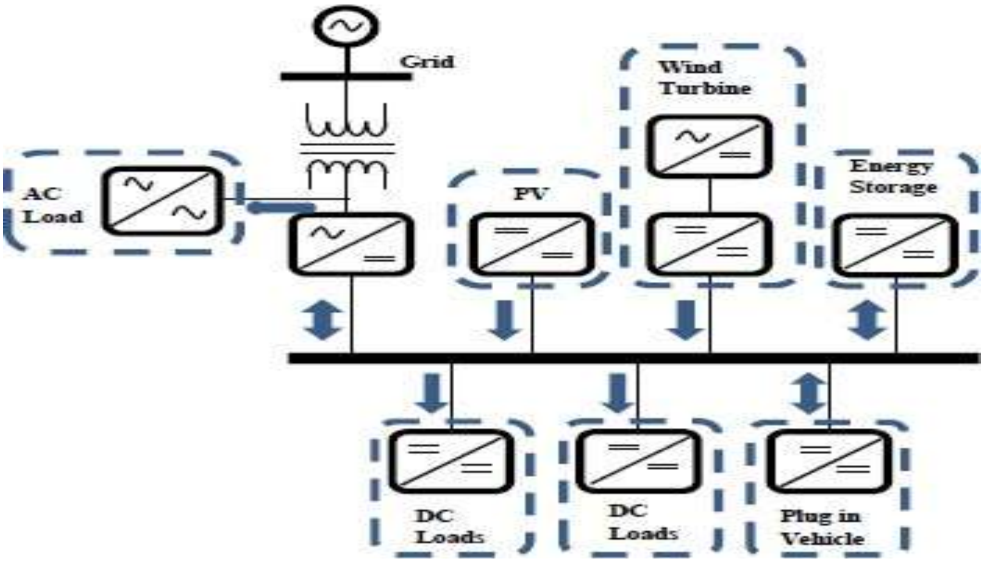

Fig.1.Basic microgrid architecture showing AC bus, DC bus

It is possible to identify three critical elements that must be considered for a microgrid to function properly:

- Dispersed generation integration:
- operation and control:
- Coordination and protection:

Finally, by linking this technology to the next chapter, we can conclude that microgrids are the foundation for developing smart grid networks.

Smart grids

Many grids and transformer substations can no longer satisfy the needs of the growth of the electricity system.As a result, the distribution network experiences more supply failures, resulting in longer periods of inactivity.To begin with, an energy storage system is a key element in addressing many problems relating to the changing configuration of distributed and electric vehicles: when demand is high it is possible to apply various electricity management logics and power supply to the electric system.

Secondly, the main aim for an intelligent grid is to monitored and manage, partly via a reliable telecommunications infrastructure system, as many components as feasible.

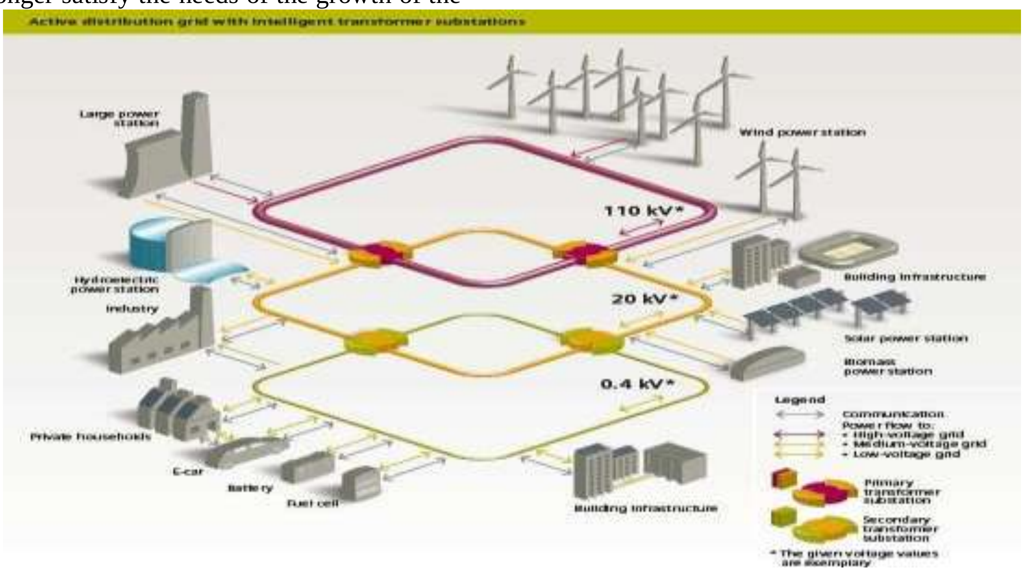

Fig.2. Active distribution smart grid implemented with intelligent transformer substations, situated in HV/MV and MV/LV grid

Integration of advanced digital communications and computers for every power system entity would provide information that must be sent and directed to monitor operations in real time and to manage them intelligently. Integration of dispersed generation. As a result, it is feasible to respond to blackouts quickly and automatically, remove the problem, and actively control the load in the distribution network.

Smart transformers

Electric power generated via scattered generation, such as wind energy or solar components, lowers the distances over which it must be transported. In other words, this depends on a reduction in grid losses and transmission losses in upstream systems.Power electronics, on the other hand, plays a significant part in the development of the electric system. In reality, power electronics converters interface the bulk of the components linked to the distribution network (either loads or sources). Furthermore, many solutions proposed to improve power system stability and reliability are based on power electronics: Solid State Transformers (SSTs), Electronic Circuit Currency Currents, Flexible AC Systems (FACTS), Active Filters and Direct Current (HVDC) may be used with these technologies (HVDC). A power electronic device distribution transformer may be an excellent choice to improve and deploy new auxiliary services.

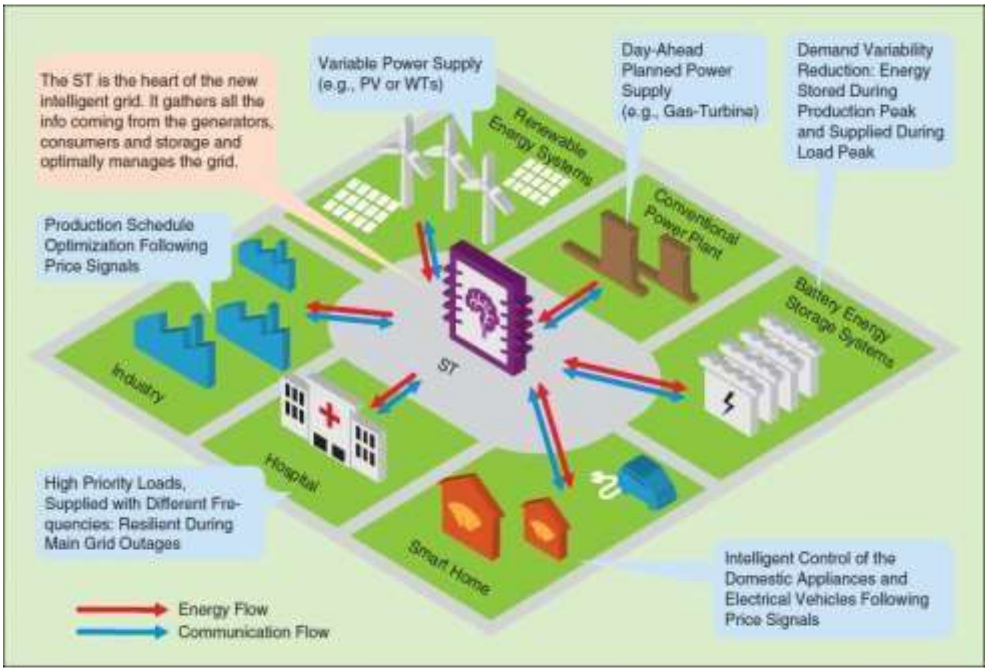

Fig. 3. Smart transformer and its role in the smart grid

As Figure 3 shows, the intelligent (centre) transformer can regulate power flow (red files) as well as communication flow (blue arrows).which influence the interior temperature of the smart transformer's power electrical components (based on semiconductors). This causes mechanical stresses and possible disintegrations to power converters, making intelligent transformers unappropriate to use in distribution networks. On the other hand, an active thermic control may be established by a modular design applied to a smart transformer: it is possible to increase internal flows via routing and thus regulate the thermal charge of the power half-conductors.

. Figure 4 depicts the suggested system's implementation. The whole procedure begins with rectifier operation. The alternating current (AC), e.g. 11Kv to 1.69*104 volts, is converted into direct current (DC).The output of the rectifier is then sent into the buck converter, which steps down the voltage from its input to the output voltage, resulting in fluctuating DC. Again, the output of the buck converter is sent into the solar panel, which is utilised as a sustainable energy source and produces 179 volts. To enhance or boost the PV array output, we will feed this 179v through the converter, which will step up the voltage to 445v, i.e. variable DC. So, the goal here is to convert the DC output voltage to an AC voltage. We will feed

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 141-155 www.ijaem.net ISSN: 2395-5252

440v into the inverter, which will convert DC power into 3-phase AC voltage, i.e., 440v. Power will be transferred to loads as a result of this.

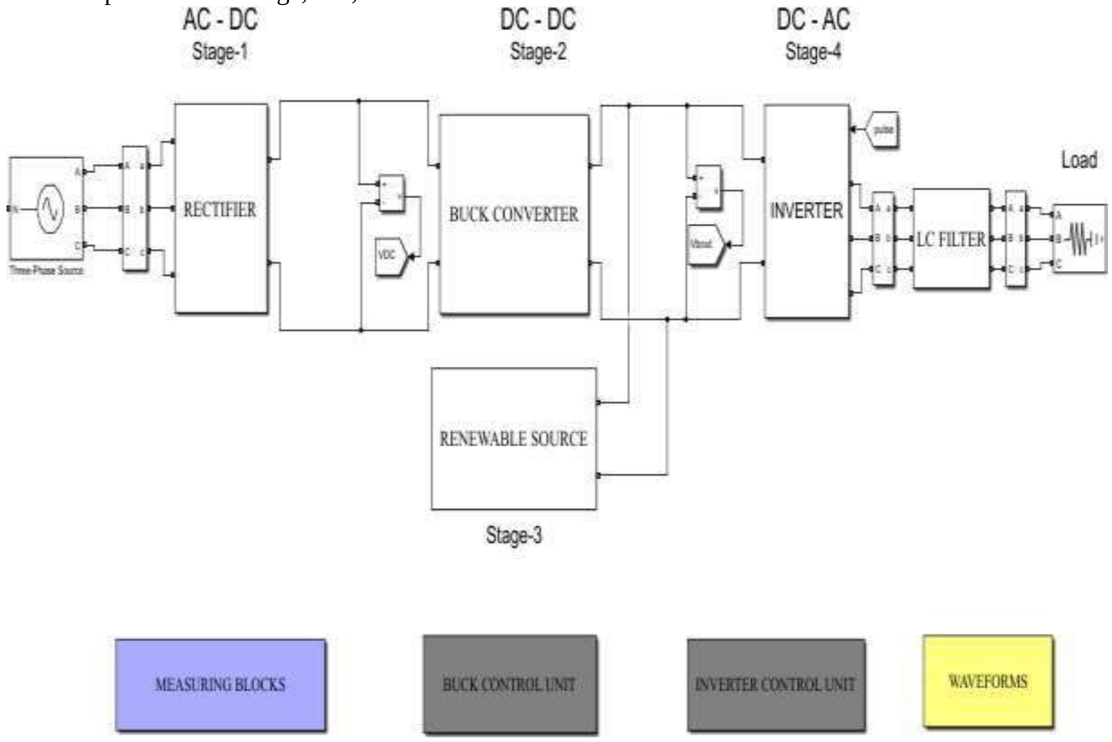

Fig.4.The suggested system's implementation

4.Block diagram

The suggested smart transformer method aims to decrease the voltage from peak to low levels. Figure 2 depicts the rectifier, buck converter, inverter, and photovoltaic array. This plan is broken down into four phases.

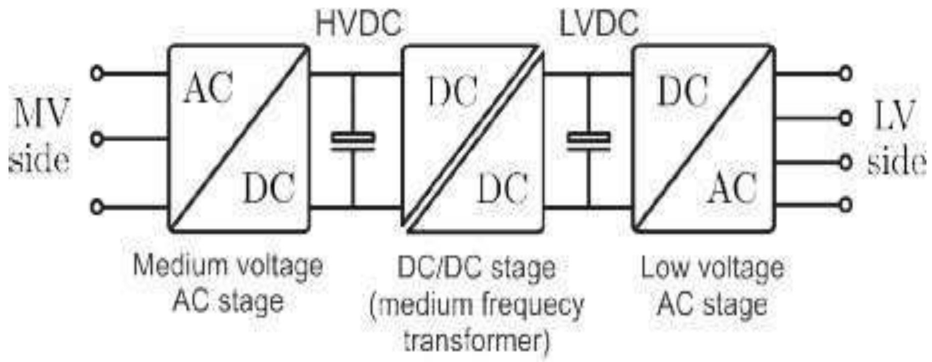

Fig.5. A sophisticated, three-stage, distribution system transformer.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 105-116 www.ijaem.net ISSN: 2395-5252

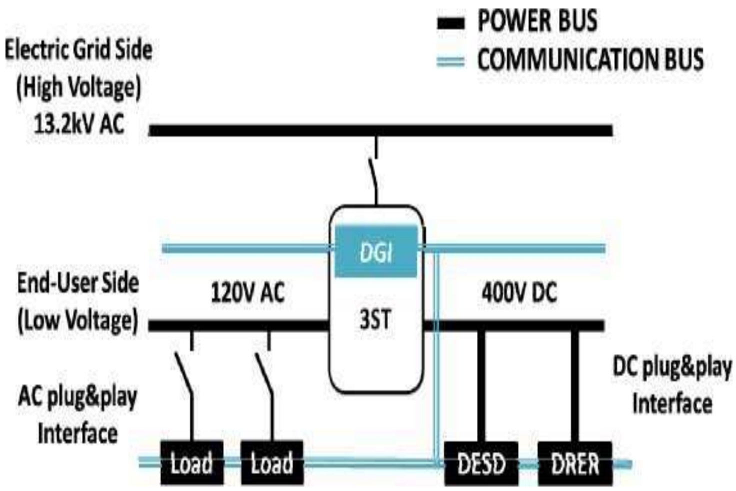

Fig. 6. A clever three-stage connecting technique for the transformer.

The distributed grid intelligence system (DGI) in each device of the intelligent transformer is one of the most important features of the three stage smart transformer., which is in charge of managing the interconnection and communication among the components of this topology. In order to regulate the power flow across a large region, this intelligent system must gather, analyse, and send data.

Voltage Converter: The first of the abovementioned electronic components is the medium volts. voltage AC/DC converter, which takes active power from the medium voltage grid to feeding on to the next step (Therefore the following network for low voltage distribution).

A cascaded H-bridge converter is utilised in the medium voltage converter design (Figure 17(b)), which are already in use on many MV drives. This technique is more flexible than the first and is the main driver of this technology, along with the low frequency working of the base cell and its low control complexity. But this H-bridge converter cannot connect to the DC and each cell needs a separate supply, requiring many DC/DC converters to finish the building. The DC connection is not accessible. In fact, a direct link is one of the biggest advantages of the intelligent transformer since an intelligent node is needed in the network to be termed "intelligent." Conversion 11 kv to 1.69*104 from AC to DC is possible through this device.

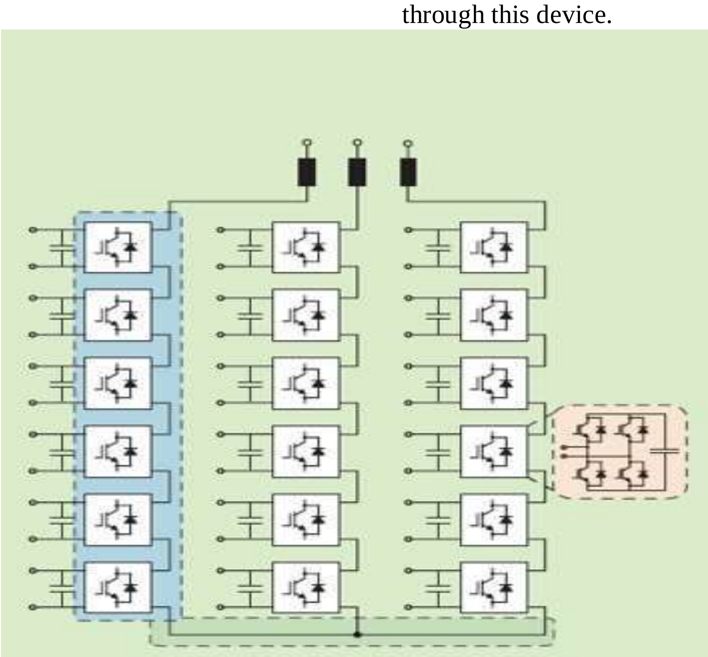

Fig.7.Medium voltage converter

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 141-155 www.ijaem.net ISSN: 2395-5252

Buck converter: The DC/DC transformer takes into account the following level of the intelligent three-stage transformer. This phase in the smart transformer design has proven to be the most complex, given its strict requirements, such as low voltage high current capacity, high frequency isolation, HV capabilities on the MV side, high rating power, and significant efficiency.

The second approach has several advantages over the first, including low electromagnetic interference (dv/dt), the possibility to utilise standard, low voltage rating and, of course, flexibility, despite the presence of a great many components. In particular, the modular structure allows a repeated strategy to increase availability and defect tolerance to be implemented.

Different converters may be used as core of intelligent module transformers, with the seriesresonant converter (SR) being the most often employed owing to its advantages of high power density, gentle switching, and high efficiency.On the other hand, the SR DC-DC converter is a highly regulated output Voltage for a wide variety of charges, often known as a DC transformer.The essential concept is that a more complicated structure may be created by utilising different DC/DC converters, particularly on the parallel side of MV and on the one side series of LV. This reduces the voltage ripple in a detailed operation on the low voltage side

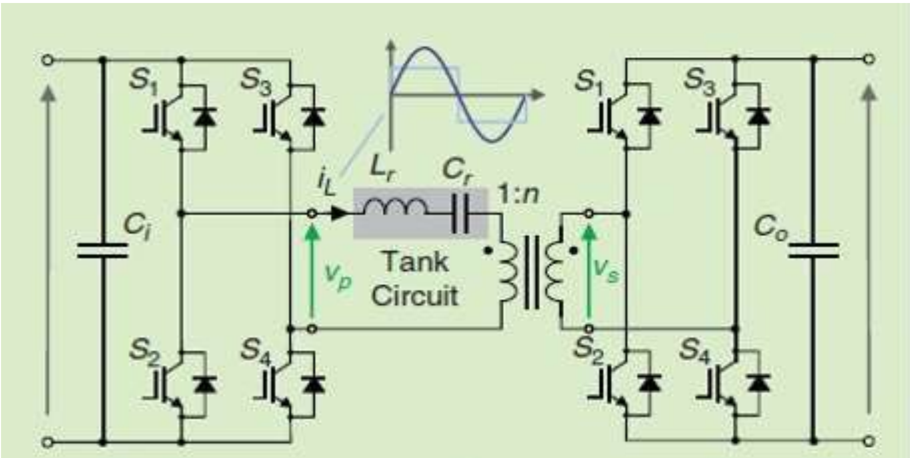

Fig.8.Scheme of DC/DC converters

This gadget transforms the Dc voltage to 449v, i.e. the DC variable.

PV array: The equipment is utilised in the distribution system as a renewable energy source. With an MPPT device, the particular voltage is maintained by modifying the cycle of service. i.e., DC 445v.

Inverter

This device is best exposed to disturbance occurrence within the Lv grid and must supply the greatest current among the general device of the intelligent transformer. A low voltage converter is the final part of the three stages of the intelligent transformer.. There is a large range of low-voltage devices, therefore the choice of topologies is also wide. The neutral wire is important and may be connected to the transformer in the distribution systems in the centre of the DC connection (particularly in the TT type).Moreover, an extra DC/DC converter may be used in all situations to rectify the voltage division between the condensers.

For this LV converter, the simplest option is the Half-Bridge (HB) type, and industry confirms the three-level converter method. This is why it is possible to utilise devices at 600v with a neutral spacer (T-type or standard), thereby boosting system efficiency and wave output. When several converters have been linked in parallel, correct controls are carried out, decreasing the size of the filter yet taking into consideration the current circulation.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 105-116 www.ijaem.net ISSN: 2395-5252

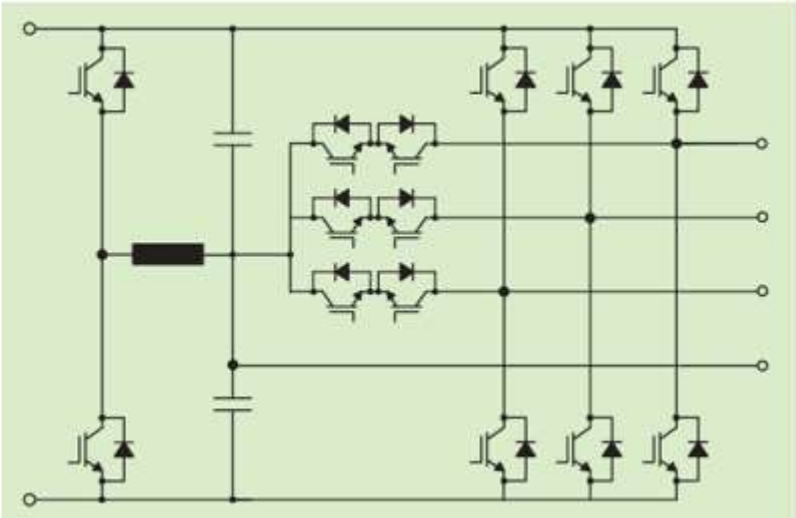

Fig.9.Possible schemes of LV converters

The inverter transforms the 445v variable DC in 440v AC power.
This rectifier is utilised in a diode bridge-designed system and MOSFET is used as a buck converter, We install the smart transformer in the grid operating system to circumvent the restrictions of transformer applications.

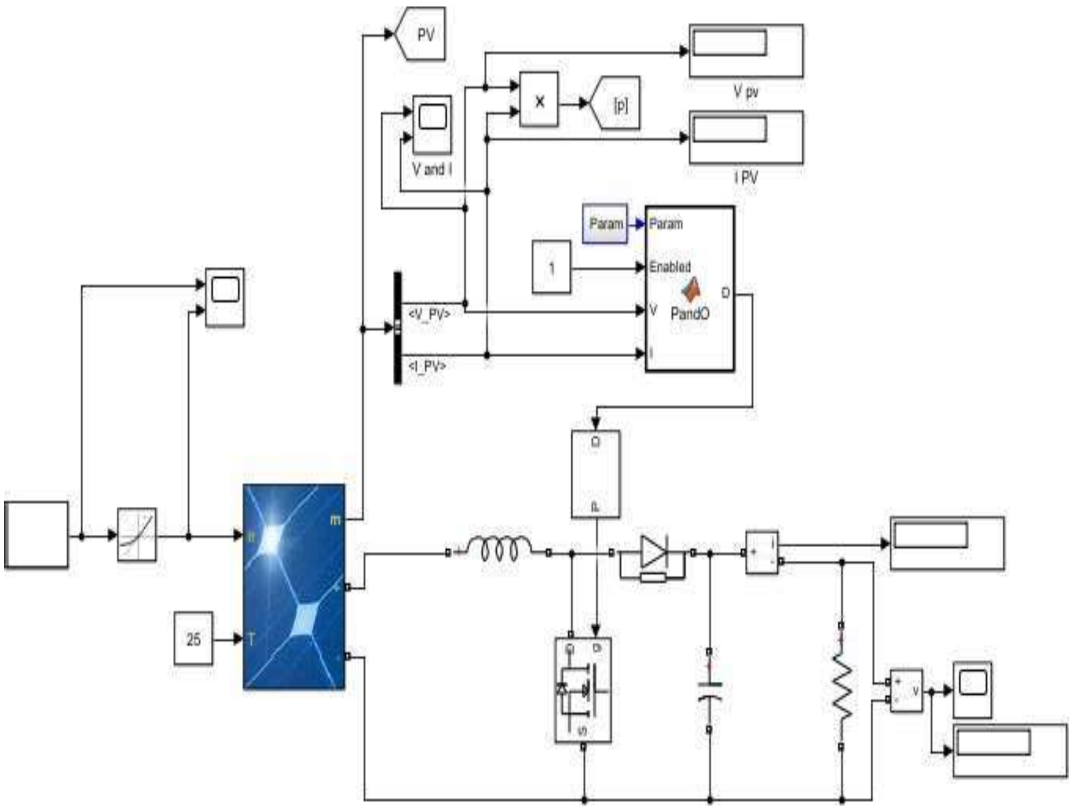

Fig.10.:BlocK diagram of the solar cell consists of MPPT(IGBT).

This is done through the construction of a Universal Bridge Circuit with the help of IGBT, utilising a device called MPP to regulate the voltage and the control function. It can run in both ways in this universal bridging circuit.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 141-155 www.ijaem.net ISSN: 2395-5252

IV. SIMULATION RESULTS:

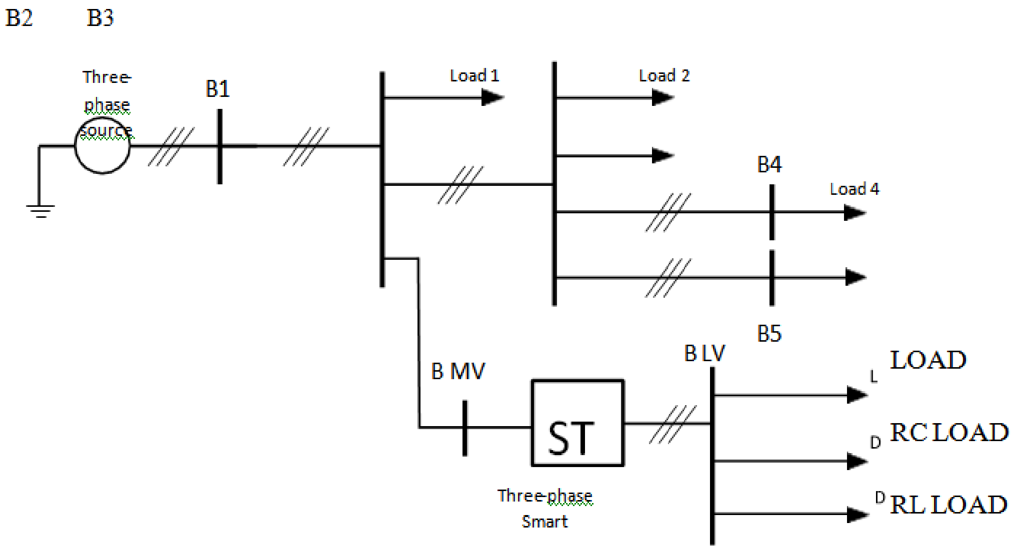

Fig. 11. Electrical network distribution scheme utilising the intelligent transformer with distorted LV grid loads.

First, three phase voltages can be analysed in the distribution network and the clear, sine quantity waves in the MV and LV networks can be maintained by 120°.

In the programme MATLAB this system is replicated using four injecting voltage converters from one block to another. The correction unit is operated at the DC output voltage of 11kv/p. Block2 works at block 1 voltage, i.e. DC. Converting voltage into a 449v or DC is a buck converter circuit. Block3 operates when the buck converter o/p voltage is injected into the pv array 179v, which is enhanced by the buck converter. The voltage increases are 445v DC. The inverter circuit changes the voltage from 445v to 440v, i.e. AC, to convert this voltage into AC block4. At this step, we are using the RLC filter arrangement as a result of the quadrature wave nature and then we receive the pure 3-stage AC Sinusoidal Waveform.

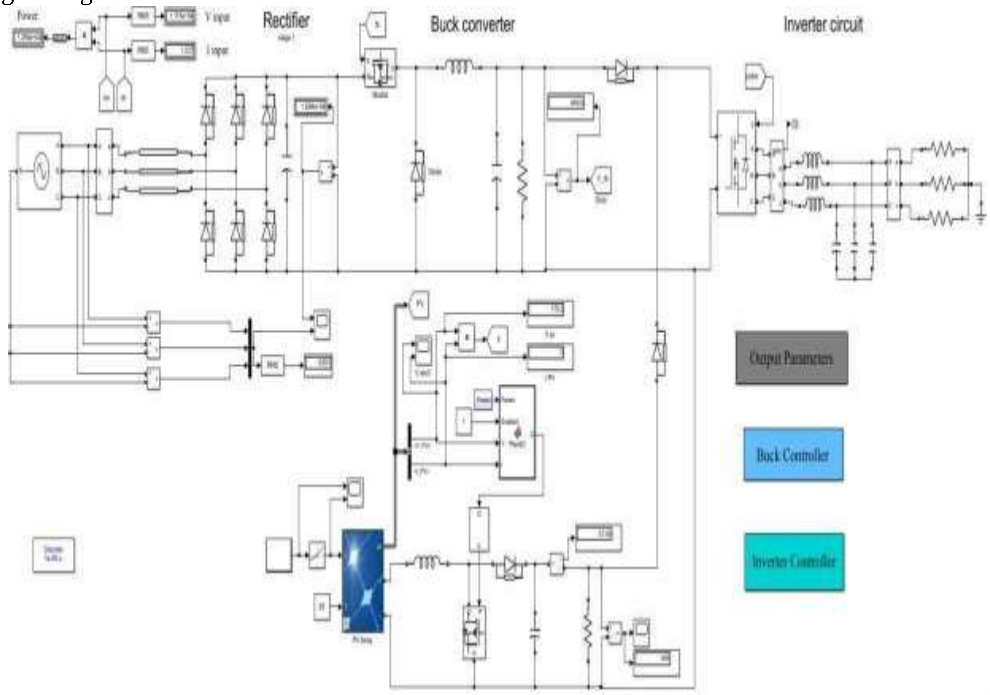

Fig.12.:Implementation of the proposed system.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 105-116 www.ijaem.net ISSN: 2395-5252

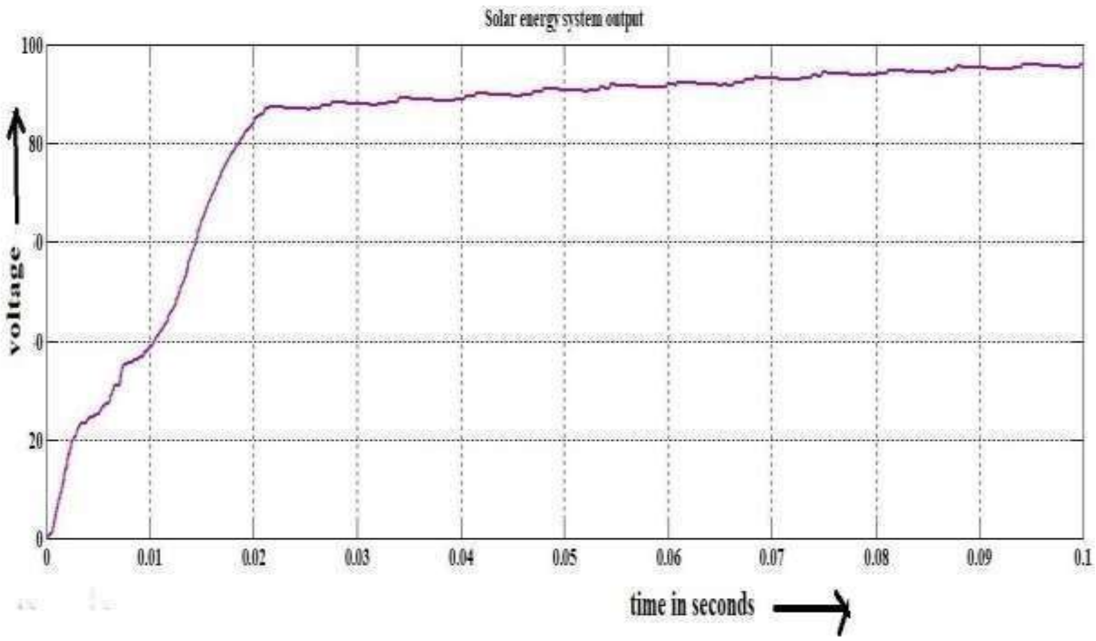

Fig.13.Rectifier output waveform.

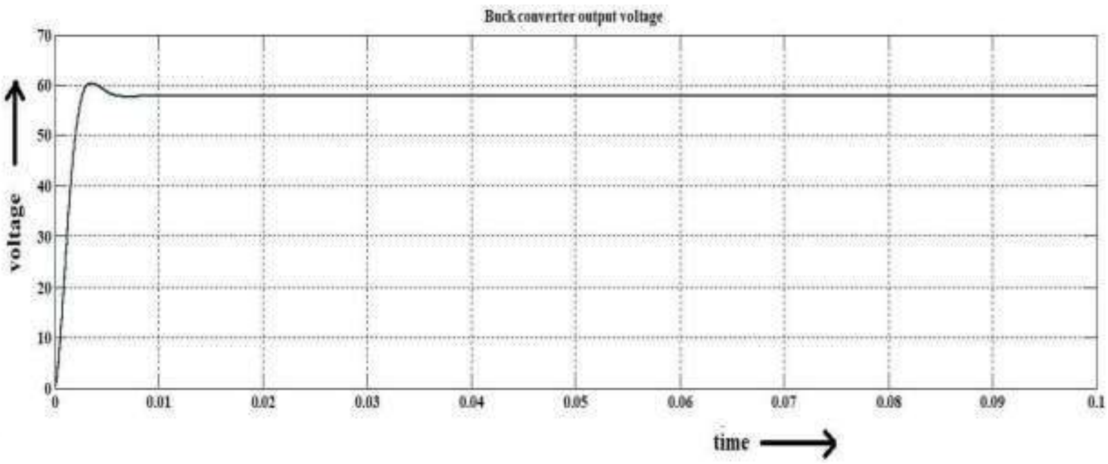

Fig 14 Buck converter waveform.

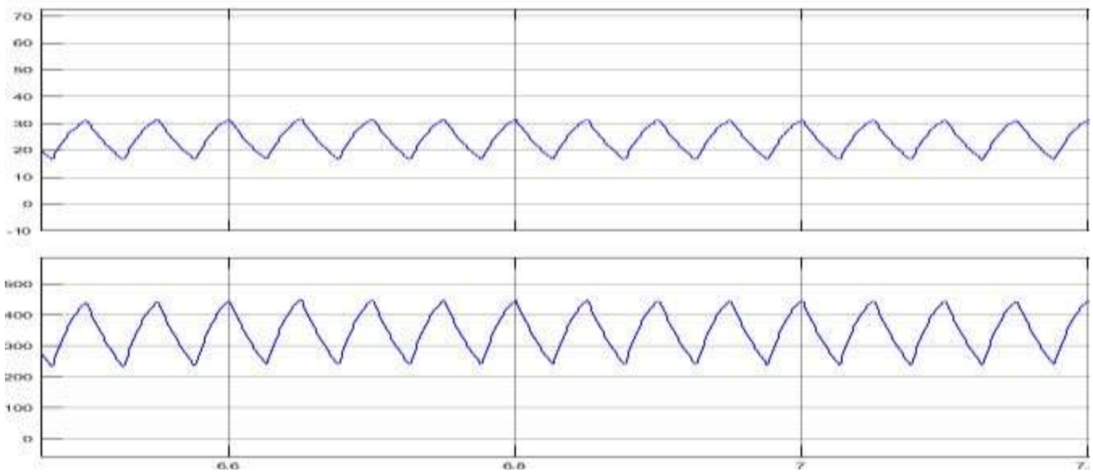

Fig.15. Boost converter output waveform.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 141-155 www.ijaem.net ISSN: 2395-5252

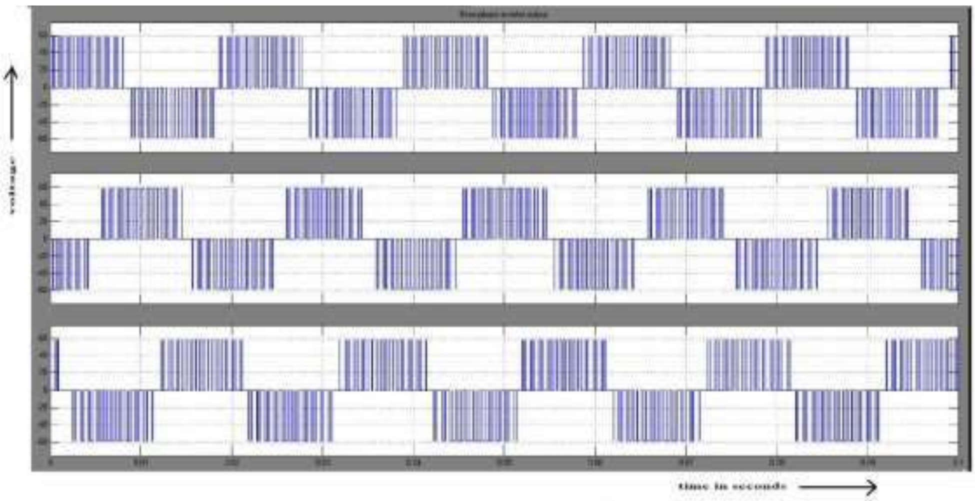

Fig 16 Three-phase output waveform inverter.

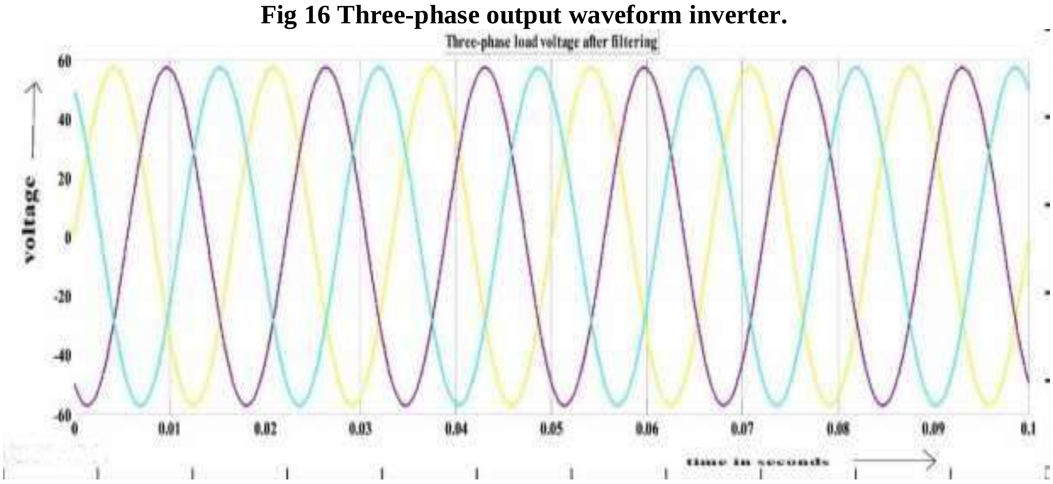

Fig 17 LC filter output voltage waveform.

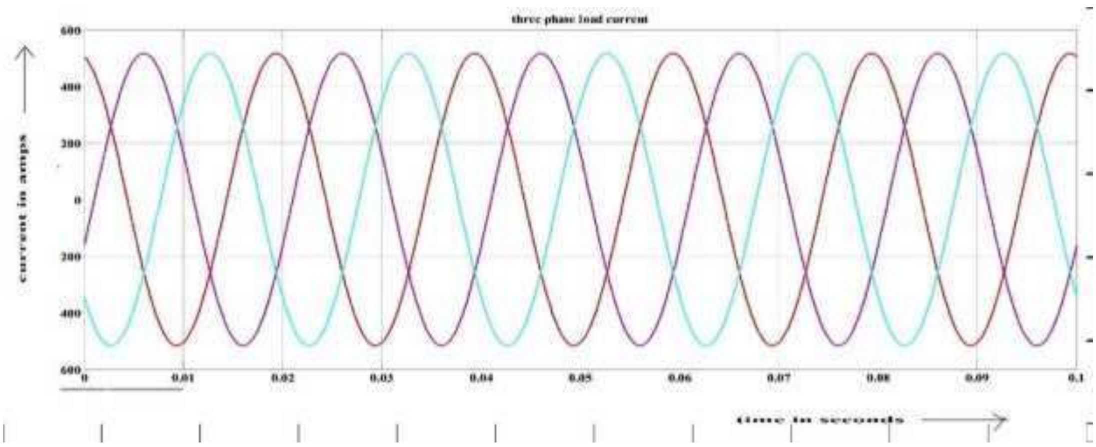

Fig 18 Three phase inverter load current waveform.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 105-116 www.ijaem.net ISSN: 2395-5252

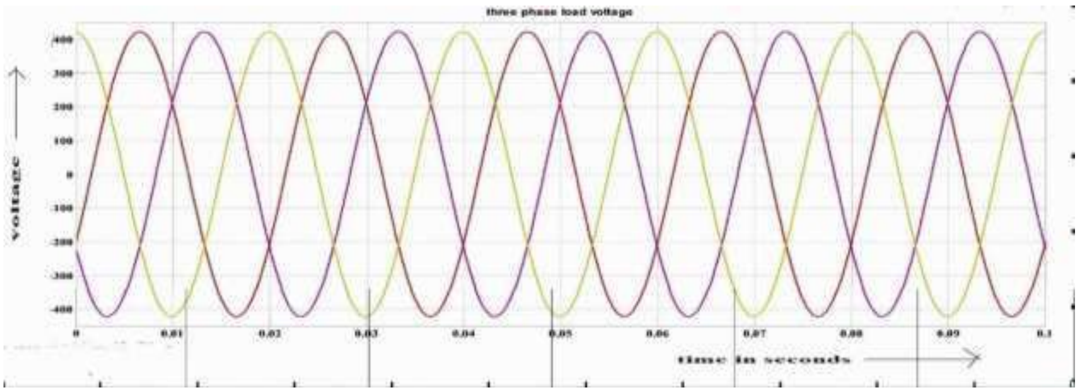

Fig 19 Three phase inverter load voltage output waveform.

There is a first- or second-order low-pass filter: the choice is based on a comparison of the block's "average-LPF work" section, in this instance. A 10 Hz cut off frequency (function) was employed as low-pass filter parameters, a ± pulsation of αc = 2α amounted a rad/s of 62,83 and a ±2/2 damping factor (Ç). The test results are acquired using scope and shown in the picture below..

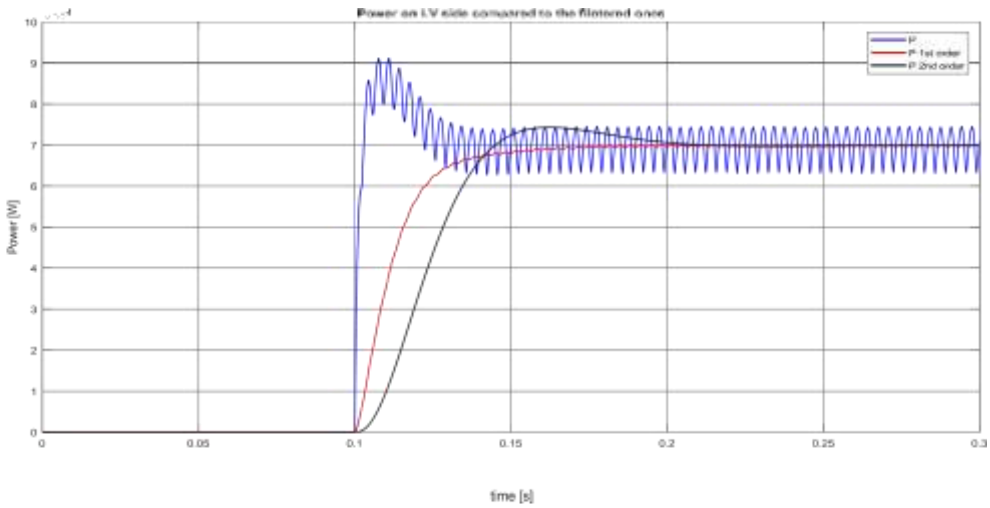

Fig. 20. Comparison of low-voltage electricity with filtered power.

Therefore, it is possible to adjust a suitable power signal called Power by utilising the second order low-pass filter rather than simply Power as before. Then, this indication may be sent to the next controller, which performs the current signal to input the controlled current sources on the main ST side. When the current maximum current value from that power is obtained using the same method as the first instance, the current signal may be collected along with an MV bus phase shift to the absc reference system to operate the main side of the intellectual transformer.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 141-155 www.ijaem.net ISSN: 2395-5252

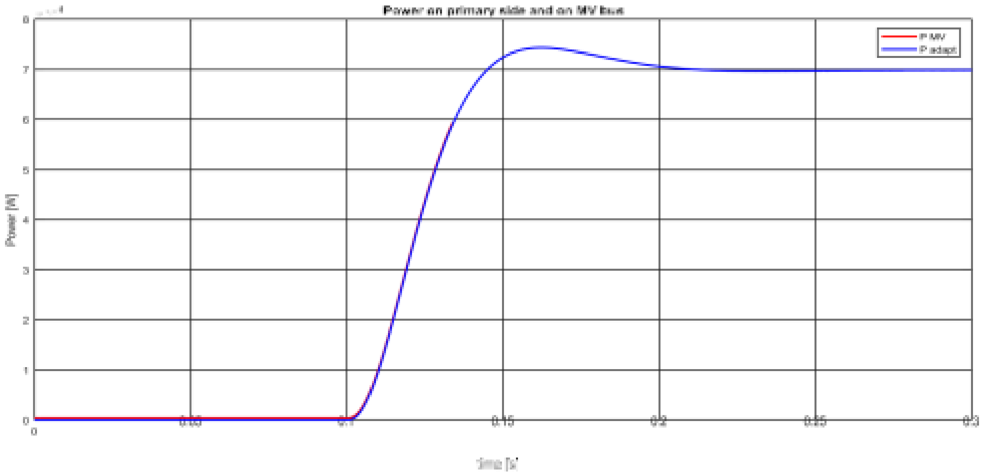

Fig. 21 A power system on the MV bus and the main ST side.

It should be noted that the power required at the main side of the smart transformer is, in this instance, like the earlier one, that of LV which has been increased by certain potential losses, Given the efficiency dividing the amount by 0.98.

In this instance, as in the previous one, it needs to be recognised that the power required on the main side is the LV that is supplemented by a number of potential losses, which are assumed to divide this amount by a rate of 0.98.

As shown in the schema, the power demand on the MV-side and the power need on the MV-bus are different. In normal circumstances, this power difference is larger since the network is loaded more than this.

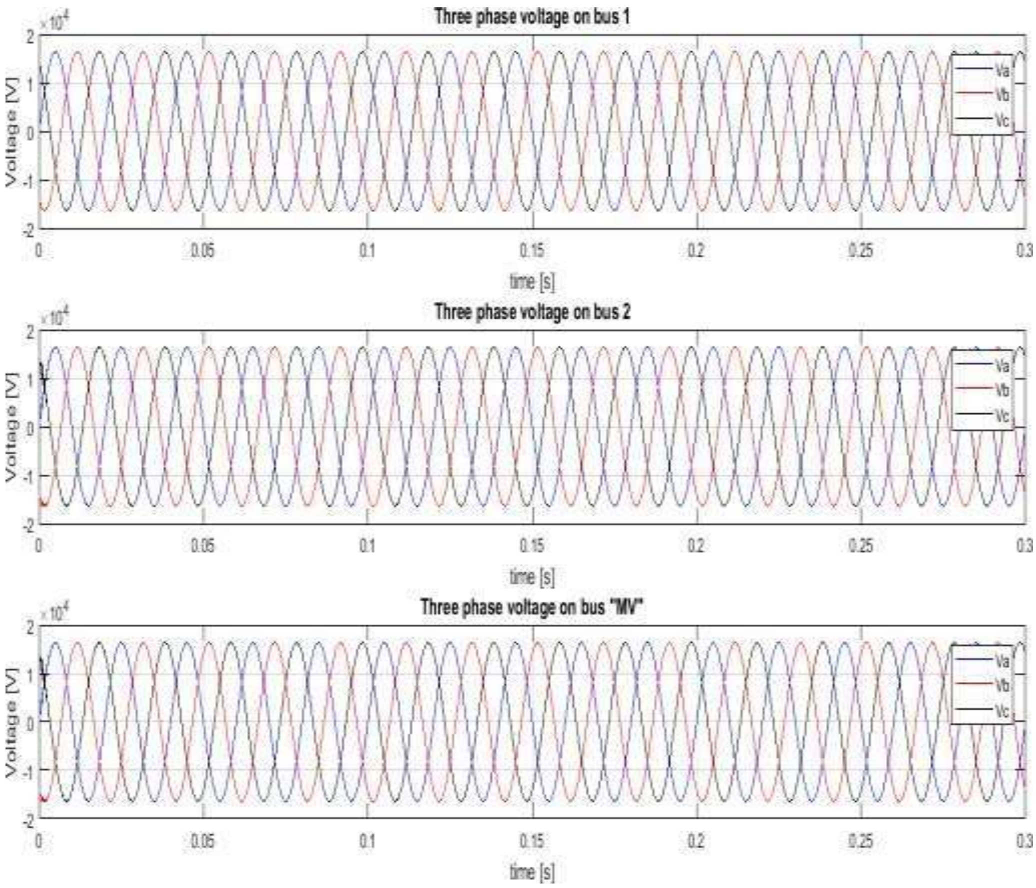

Fig. 22. Medium-voltage network with three phase voltages.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 105-116 www.ijaem.net ISSN: 2395-5252

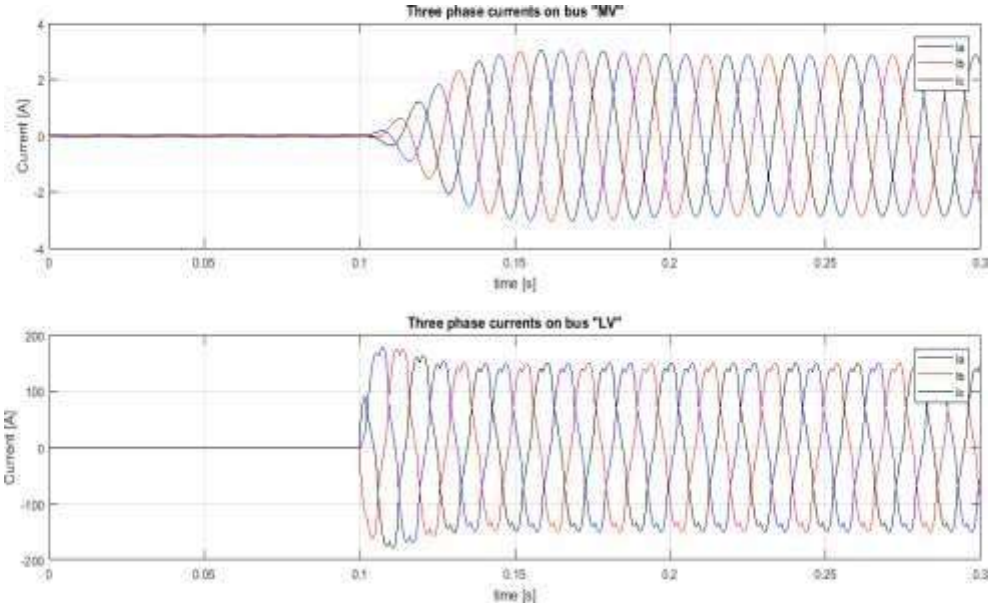

Fig. 23 Three phase currents on MV bus and in low voltage network.

Also, when the generator must supply an extra current (power) after 0.1s to guarantee the proper working of MV and LV consumers, the load introduction impact may be seen from the three-phase current of Bus 1 (Figure 24).

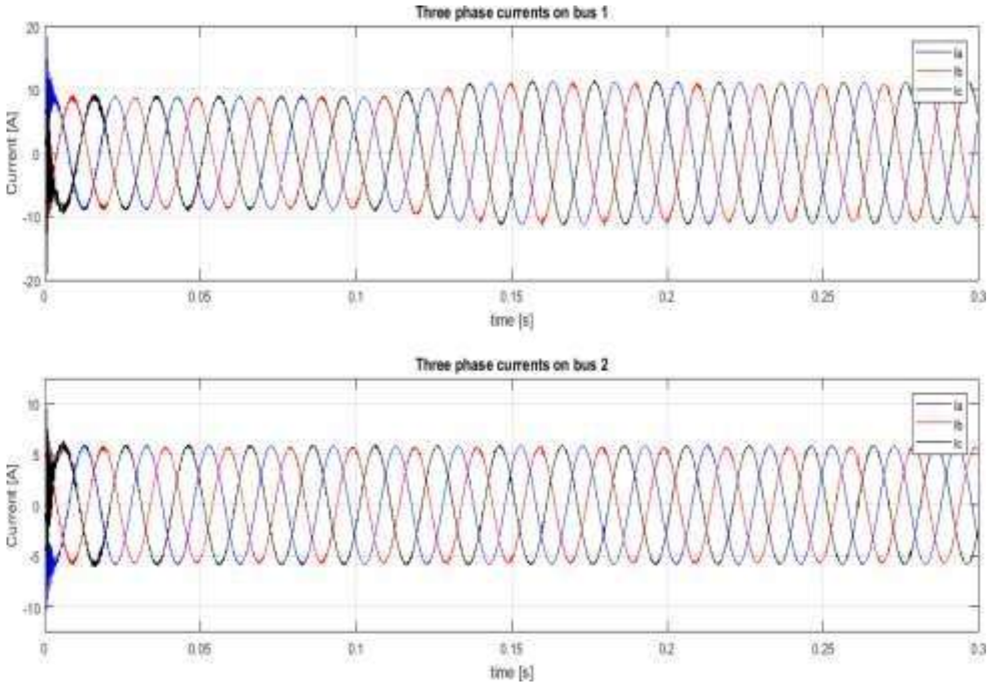

Fig.24.Three phases currents in MV network on bus 1 and on bus 2.

On the other hand, as has been researched up to now, the introduction of distorting charges into the LV grid does not influence Buss 2 currents and the currents are maintaining the correct sinusoidal form 120° from each other.

V. CONCLUSION

The possibilities of a contemporary gadget, the intelligent transformer, have been analysed. The subject of microgrids and smart grid systems, concentrating particularly on Smart Transformers, was the emphasis of this contemporary approach to the management of distribution networks. This was started by a diffused generation and its effect on electrical power quality.

With the help of an intelligent transformer, low- and medium voltage distribution networks may be separated, so that disruptions on both sides can be mitigated and compensated. Furthermore, the smart transformer comprises of a control point for the whole grid between the voltage levels. You can control voltage, active and reactive power, using a unit power factor, variable of filter voltage and supported voltage at medium voltage.. If highharmonic loads are present, intelligent transformers operate as an active filter, decrease hazardous transformer situations and improve the overall electric energy quality of the grid. The intelligent transformer serves as a division between LV and MV grid, has been observed and demonstrated. It really allows operation of various power factors on each side, and any imbalances and distortions in the LV network may be reduced and offset to prevent the MV network from being affected

The best option is to increase the issue of energy efficiency and energy quality with the increased demand for electricity. There are so many nations in various areas of feverishness where the direct PV array may attain up to its strength or density. The solar system is thus seen as an important resource. A comprehensive depiction of the grid-connected system in the PV array is provided in this document.

REFERENCES

[1] A. M. Hava, T. A. Lipo and W. L. Erdman. “Utility interface issues for line connected PWM voltage source converters: a comparative study”, Proceeding of APEC’95, Dallas (USA), pp. 125-132, March[1].

[2] Y. Li, Q. Sun, T. Dong, and Z. Zhang, "Energy management strategy of ac/dc hybrid microgrid based on power electronic transformer," in 2018 13th IEEE Conf. Ind. Electron. Applicant. (ICIEA), May 2018, pp. 2677– 2682. [2]

[3] M. Wang, A. J. Vandermaar, and K. D. Srivastava, “Review of condition Assessment of power transformers in service,” IEEE Elect. Insul. Mag., vol. 18, no. 6, pp. 12–25, Nov./Dec. 2002[3].

[4] G. De Carne, G. Buticchi, M. Leisure, and C. Vournal, “Frequency-based overload control of smart transformer,” in IEEE Power Tech, 2015[4].

[5] H. Gabbar and S. Khairy, "Smart distribution system Volt/VAR control using the intelligence of smart transformer." 2016 IEEE. Smart Energy GridEngineering (SEGE), pp. 52-56, 2016[5].

[6] J. V. D. Jayasooriya, M. M. H. C. N. Mahalaksha, P. J. Binduhewa, J. R.S. S. Kumara, “ Investigation of a Smart Transformer”, IEEE Region 10conference Tencon, pp. 1- 6, 2015[6].

[7] R. Pena-Alzola, G. Gohil, L. Mathe, M. Liserre, and F. Blaabjerg,“Review of modular power converters solutions for smart transformer in the distribution system," in IEEE Energy Conversion Congress and Exposition (ECCE), Sept 2013, pp. 380–387[7].4321`x`