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AFLL-Based Control Technique for Grid Interfaced Three Phase PV System By Using Fuzzy Logic Controller

D.Mahesh Kumar,
PG Scholar, MTech
Sir CRR College of Engg ,Eluru

Dr. V S R Pavan Kumar.Neeli M.E, Ph.D
Associate Professor,
Sir CRR College of Engg ,Eluru

Abstract

In this study, an Advanced Frequency Locked Loop (AFLL)-based fuzzy logic control approach for a three-phase double-stage grid-interfaced solar photovoltaic (PV) system is being developed. This AFLL-based algorithm isolates the system in the event of a grid fault, extracts the essential components of the load current, eliminates harmonics, balances the grid current, and optimises system performance under distorted grid conditions. The harmonic distortion is decreased by the fuzzy logic controller, which also evaluates the precise values. In order to regulate voltage, the fuzzy logic controller replaces the PI controller. In a long radial network, the distant endpoints have a voltage quality issue, but this controller preserves the grid power quality by supplying the necessary reactive and active power to the grid. Even in the worst cases of DC offset, solar insolation variation, load unbalancing, grid faults, voltage distortion, voltage unbalance, and voltage swell/sag, the PV system's Voltage Source Converter (VSC) is able to supply PV energy to the grid. An adjustable DC link voltage is used to lower the VSC switching losses. Using the matlab/simulink software, the effectiveness of the proposed technique is evaluated.

Introduction

In present times, renewable energy systems (RES), such as solar photovoltaic (PV), biogas, wind, and hydro energy systems are emerging as an alternative to conventional energy sources of energy for the production of electric energy. Due to low maintenance and availability of PV energy in surplus, it emerges as a best alternative of conventional energy. However, the grid in India is very poor and degraded. Power quality (PQ) problems in the grid, causes maloperation of the apparatus connected in the distribution network. The cause of PQ problem is the nonlinearity of the local load connected to the network. . PQ indices determine the level of the PQ problem in the grid .

A method for modeling and simulation of PV array is demonstrated in [8]. The productivity of PV system depends upon the power extraction by the Maximum Power Point Tracking (MPPT). There are various controls related to MPPT described in [9]. The perturb and observe (P&O)-based MPPT technique is presented.

Another hybrid filter with passive filter and active shunt filter with conservative power theory is demonstrated in [18]. The system behavior under the aforementioned controls is declined during the presence of dc offset in the load currents. For mitigation of the dc component from the currents, generalized integrator (GI)-based controls are used.

System Structure

The structure of the system is depicted in Fig. 1. It comprises of a three phase grid, a ripple filter, interfacing inductors, a VSC,

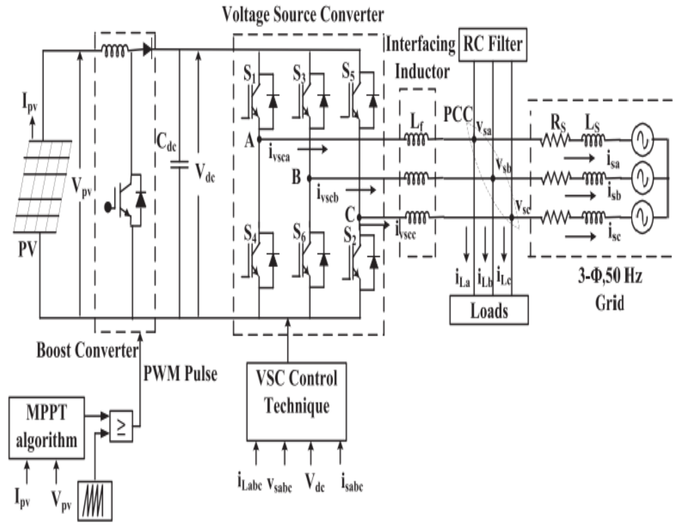
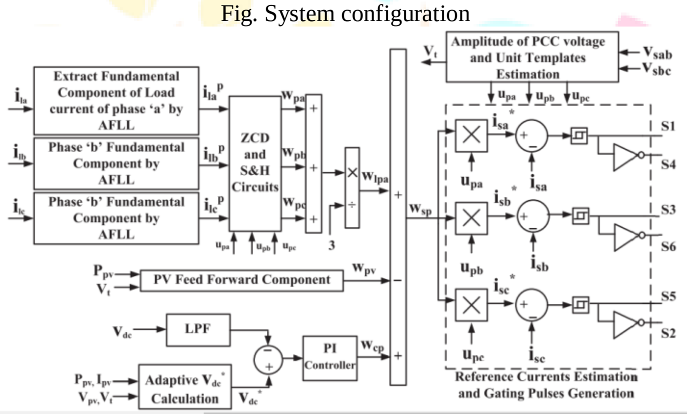
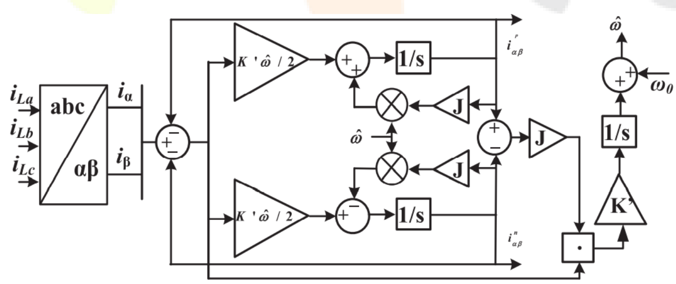


Fig. System configuration



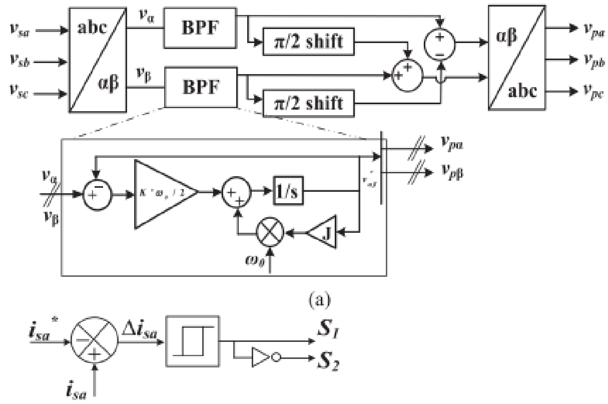


a dc–dc converter, a PV array, diode bridge rectifier (DBR)- based nonlinear load, and the dc link capacitor. The RC filters are used for the mitigation of the PCI voltage ripples. PCI voltage ripples are due to the VSC switching. The ac inductors are used for the reduction of the ripples in the VSC currents. The dc–dc boost converter is used as an intermediate stage between PV array and VSC to feed PV array power to the grid.

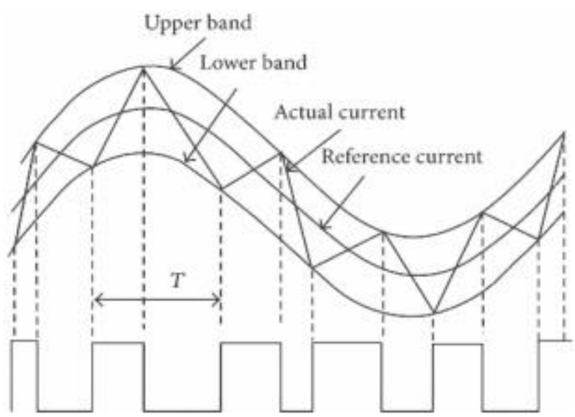
While "power quality" is a convenient term for many, it is the quality of the voltage rather than power or electric current that is actually described by the term. Power is simply the flow of energy and the current demanded by a load is largely uncontrollable.

CONTROL APPROACH

The basic layout of the control algorithm is demonstrated in Fig. 2. This control algorithm is further classified into two subsections—-MPPT control for the boost converter and VSC control. An INC-based MPPT is applied on the boost converter for



for the boost converter operation is calculated as



(b)

For the generation of the gating signal of the boost converter, the calculated duty ratio (D) is compared with the sawtooth signal to generate the gating pulse for the boost converter. In case of grid fault near to PCI, the PCI voltage falls below a certain level (vsabc,min), the pulses of the boost converter are withdrawn by making the duty ratio zero. The adaptive dc link voltage (V ∗ dc) is estimated as

$$V_{\mathrm{dc}}^{*} = \lambda\sqrt{3}V_t \qquad (2)$$

where, λ is the loss compensating component and Vt is amplitude of terminal PCI voltage. The control scheme is described as follows. A. VSC Switching Control Algorithm An AFLL-based algorithm is used for the extraction of FCLC for the estimation of reference grid currents for generation of gating pulse for the VSC, which is presented in Fig. 2(a)–(b). The fundamental aim of this method for VSC is to adjust dc link voltage dynamically while taking into account the grid voltage variations. 1) UT Estimation: The sensed PCI line voltages (vsab, vsbc) are used to estimate three phase voltages (vsa, vsb and vsc).These voltages are fed to bandpass filters to obtain PSCs as shown in Fig. 3(a). The bandpass filter extracts PSCs from the distorted and unbalanced grid voltages for the estimation of the UTs. These filtered outputs are used in estimation of in-phase UTs (upa, upb, upc) as

$$u_{pa} = \frac{v_{pa}}{V_t},\ u_{pb} = \frac{v_{pb}}{V_t},\ u_{pc} = \frac{v_{pc}}{V_t} \qquad (3)$$

Where Vt is amplitude of PCI voltages and calculated as

$$V_t = \sqrt{\frac{2}{3} \times (v_{pa}^2 + v_{pb}^2 + v_{pc}^2)}. \qquad (4)$$

2) Estimation of FCLC: Fig. 2(b) shows the structure of AFLL [23], [24]. The three phase load currents (iLa, iLb and iLc) are converted in α-β domain with Clark’s transformation.

$$\begin{pmatrix} i_\alpha \\ i_\beta \end{pmatrix} = \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{pmatrix}. \qquad (5)$$

From Fig. 2(b), the transfer function is obtained as

$$i^p_{\alpha\beta} = \frac{\hat{\omega}K}{(s+\hat{\omega}K)^2+\hat{\omega}^2} \begin{Bmatrix} (s+\hat{\omega}K) & -\hat{\omega} \\ \hat{\omega} & (s+\hat{\omega}K) \end{Bmatrix} \begin{Bmatrix} i_\alpha \\ i_\beta \end{Bmatrix}. \qquad (6)$$

The AFLL controller is explained in Appendices. FCLC is extracted from the output of the controller using inverse Clark's transformation. This FCLC is passed through sample and hold logic and zero crossing detectors, and is multiplied by UTs to obtain fundamental load currents (wpa, wpb and wpc). The net weight component of the load current for a three phase system is calculated as'

$$w_{lpa} = \left(\frac{w_{pa}+w_{pb}+w_{pc}}{3}\right). \qquad (7)$$

3) DC Link Voltage PI Controller: For the reduction in VSC losses and its unwanted tripping, the dc link voltage has to be adaptable. For calculation of loss component, V ∗ dc is compared with Vdc (sensed dc voltage) to obtain error. This error is given to a PI controller and loss component is obtained. The subsequent equations demonstrate the above explanation as

$$w_{cp}(n) = (k_{pd}+k_{id}/s)\left\{V^*_{\mathrm{dc}}(n) - V_{\mathrm{dc}}(n)\right\} \qquad (8)$$

where ΔVdc (n) and ΔVdc (n-1) are errors of Vdc, kpd is proportional and kid is integral gains constants. 4) PV Array Component Calculation: The PV array component (wpv) for the reduction in oscillations is computed as

$$w_{pv}(n) = \frac{2}{3} \times \frac{P_{pv}(n)}{V_t}. \qquad (9)$$

GRC Estimation: For the gross weight for current component estimation of reference grid current, PV power term is deducted from dc-link loss component. It is estimated as

$$w_{sp} = w_{lpa} + w_{cp} - w_{pv}. \qquad (10)$$

The reference grid currents are estimated as

$$i^*_{sa} = \begin{cases} w_{sp}.u_{pa} & \text{If } v_{sabc} > v_{sabc,\min} \\ 0 & \text{Otherwise} \end{cases}$$

$$i^*_{sb} = \begin{cases} w_{sp}.u_{pb} & \text{If } v_{sabc} > v_{sabc,\min} \\ 0 & \text{Otherwise} \end{cases}$$

$$i^*_{sc} = \begin{cases} w_{sp}.u_{pc} & \text{If } v_{sabc} > v_{sabc,\min} \\ 0 & \text{Otherwise} \end{cases}. \qquad (11)$$

Here, vsabc are the grid voltages. During grid fault near to the PCI, if the grid voltages fall below a certain value (vsabc,min), the GRC are instantly made zero in order to protect the system and the equipment connected from the severe fault currents. Normally, when the system voltage falls For generation of the gate pulses for the VSC, these current errors are passed to the hysteresis current controller (HCC) as illustrated in Fig. 3(b). The band of the HCC is taken as ±0.01, which is physically realizable

SIMULATION THEORY

MATLAB (Matrix Laboratory) is a numerical registering condition and fourth-age programming language. Created by Math Works, MATLAB permits grid controls, plotting of capacities and information, usage of calculations, formation of UIs and interfacing with projects written in different dialects, including C, C++, Java, and Fortran. In spite of the fact that MATLAB is proposed principally for numerical figuring, a discretionary tool compartment utilizes the MPAD representative motor, enabling access to emblematic registering abilities. An extra bundle, Simulink, includes graphical multi-space recreation and Model-Based Design for dynamic and installed frameworks. In 2004, MATLAB had around one million clients crosswise over industry and the scholarly community. MATLAB clients originate from different foundations of designing, science, and financial matters. MATLAB is generally utilized in scholarly and inquire about establishments just as modern ventures.

SIMULINK, created by Math Works, is a business device for displaying, reproducing and examining multi-space dynamic frameworks. Its essential interface is a graphical square outlining device and an adaptable arrangement of square libraries. It offers tight combination with whatever is left of the MATLAB condition and can either drive MATLAB or be scripted from it. SIMULINK is generally utilized in charge hypothesis and advanced flag preparing for multi-space reproduction and Model-Based Design.

SIMULINK is a square graph condition for multi-space reenactment and Model-Based Design. It bolsters framework level structure, reproduction, programmed code age, and ceaseless test and check of installed frameworks. SIMULINK gives a graphical supervisor, adaptable square libraries, and solvers for displaying and mimicking dynamic frameworks. It is coordinated with MATLAB, empowering you to consolidate MATLAB calculations into models and fare reenactment results to MATLAB for further investigation.

Fuzzy Logic System

Fuzzy logic is a complex mathematical method that allows solving difficult simulated problems with many inputs and output variables. Fuzzy logic is able to give results in the form of recommendation for a specific interval of output state, so it is essential that this mathematical method is strictly distinguished from the more familiar logics, such as Boolean algebra. This paper contains a basic overview
of the principles of fuzzy logic

Today control systems are usually described by mathematical models that follow the laws of physics, stochastic models or models which have emerged from mathematical logic. A general difficulty of such constructed model is how to move from a given problem to a proper mathematical model. Undoubtedly, today's advanced computer technology makes it possible; however managing such systems is still too complex.These complex systems can be simplified by employing a tolerance margin for a reasonable amount of imprecision, vagueness and uncertainty during the modelling phase. As an outcome, not completely perfect system comes to existence; nevertheless in most of the cases it is capable of solving the problem in appropriate way. Even missing input information has already turned out to be satisfactory in knowledge-based systFuzzy logic allows to lower complexity by allowing the use of imperfect information in sensible way. It can be implemented in hardware, software, or a combination of both. In other words, fuzzy logic approach to problems' control mimics how a person would make decisions, only much faster.

The fuzzy logic analysis and control methods shown in Figure 1 can be described as:

1. Receiving one or large number of measurements or other assessment of conditions existing in some system that will be analyzed or controlled.
2. Processing all received inputs according to human based, fuzzy "if-then" rules, which can be expressed in simple language words, and combined with traditional non-fuzzy processing.
3. Averaging and weighting the results from all the individual rules into one single output decision or signal which decides what to do or tells a controlled system what to do. The result output signal is a precise defuzzified value.
4. The following is Fuzzy Logic Control/Analysis Method diagram.

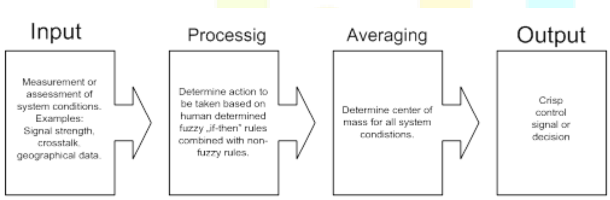


Figure The fuzzy logic Control-Analysis method

In order to operate fuzzy logic needs to be represented by numbers or descriptions. For example, speed can be represented by value 5 m/s or by description "slow". Term "slow" can have different meaning if used by different persons and must be interpreted with respect to the observed environment. Some values are easy to classify, while others can be difficult to determine because of human understanding of different situations. One can say "slow", while other can say "not fast" when describing the same speed. These differences can be distinguished with help of so-called fuzzy sets.

Usually fuzzy logic control system is created from four major elements presented on Figure fig 6.2 zzification interface, fuzzy inference engine, fuzzy rule matrix and defuzzification interface. Each part along with basic fuzzy logic operations will be described in more detail below.

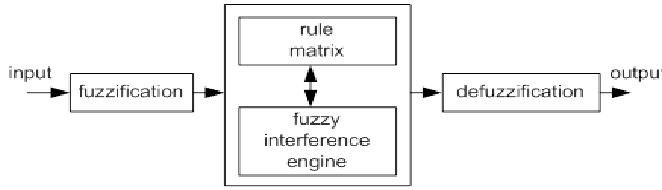


Figure - Fuzzy logic controller

Results and output analysis:-

Block diagram& Control diagram

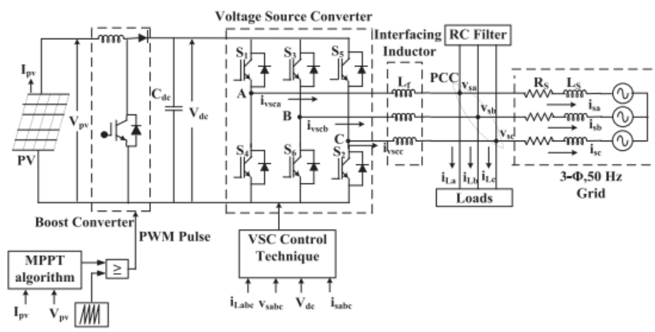


Fig. Overall control block diagram of the proposed method

Software Requirements

- **Software configuration:**
- Operating system : windows 7/8/10
- Application software : matlab/simulink software
- **Hardware configuration:**
- Ram : 8 GB (min)
- Processor : I3 / I5 (mostly prefer)

Applications of Proposed method

- Grid connected solar PV Applications
- Power quality improvement applications.
- Residential applications

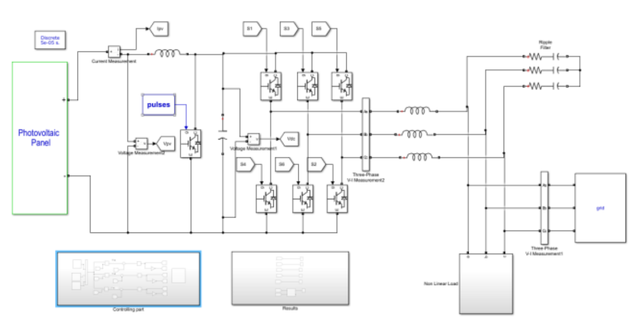


Figure **Schematicdiagram**

Case A

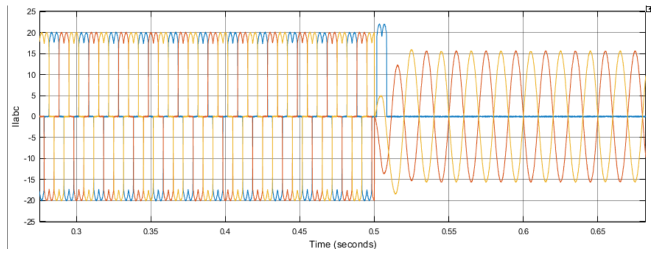


Figure IIba

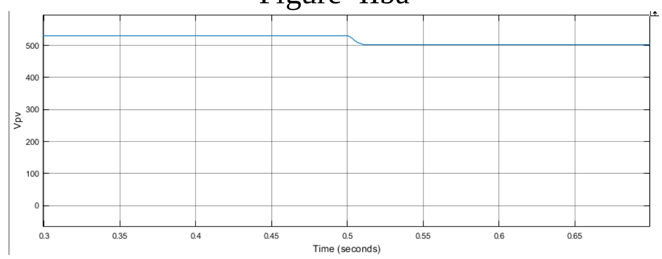


Figure Vpv

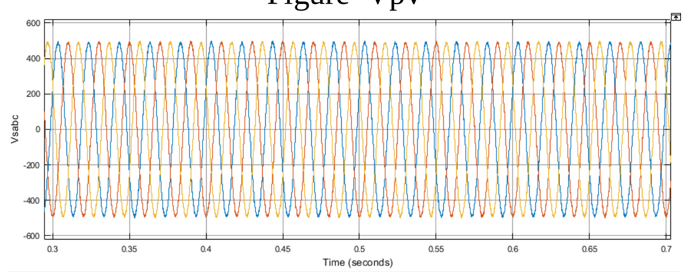


Figure Vsabc

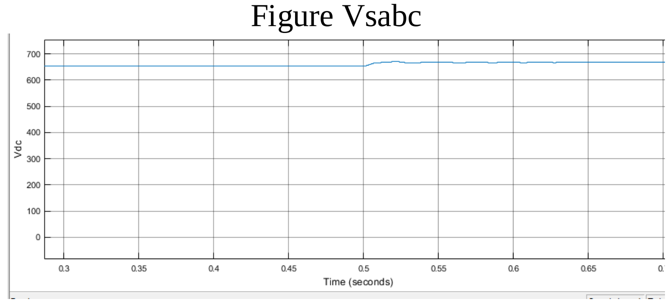


Figure Vdc

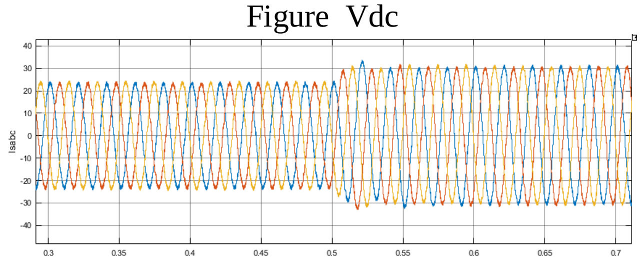


Figure Isabc

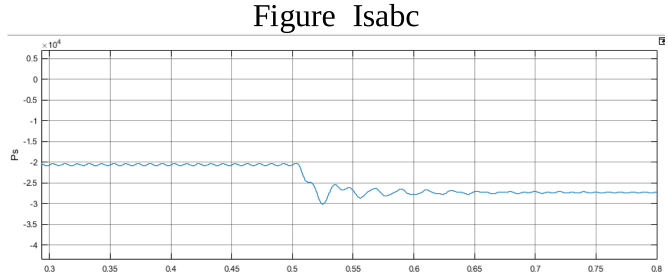


Figure Ps

Case b

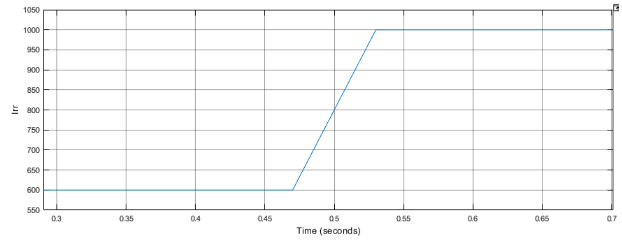


Figure Irr

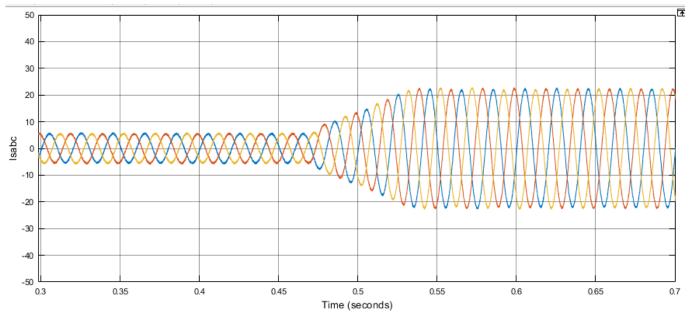


Figure Isabc

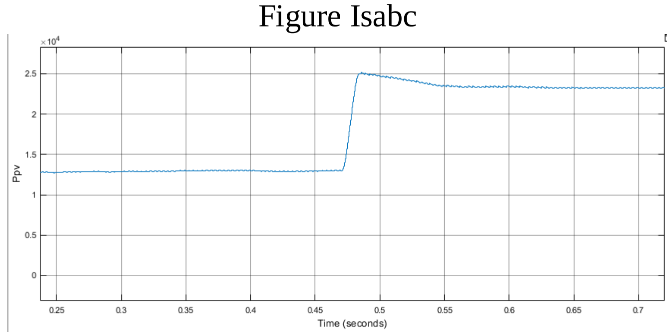


Figure Ppv

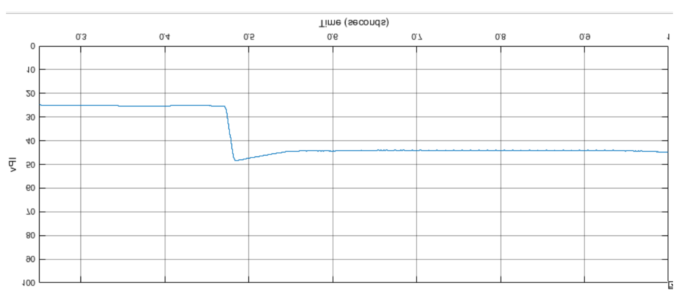


Figure Ipv

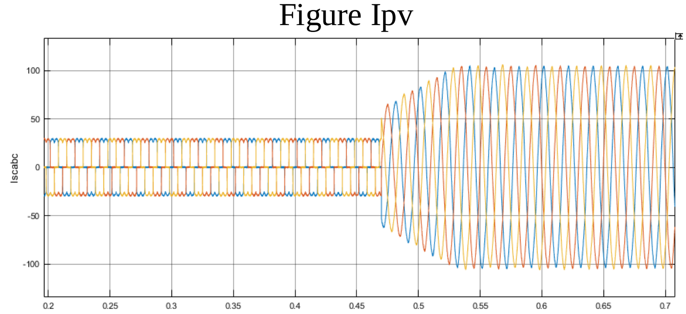
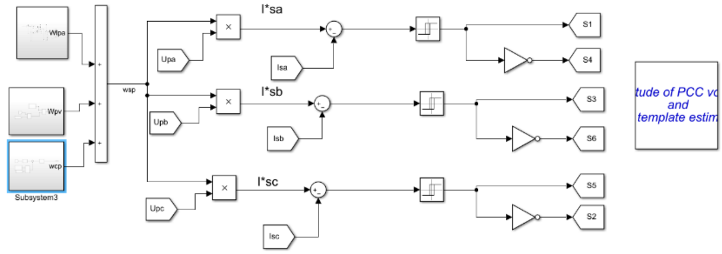


Figure Iscabc.

Results and Discussions:-



Case A :-

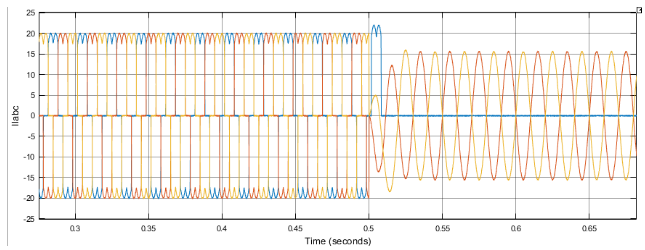


Figure **Ilabc**

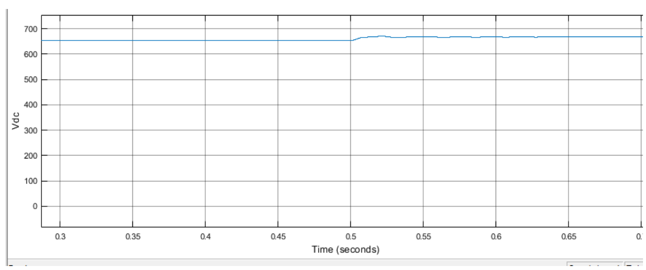


Figure **Vdc**

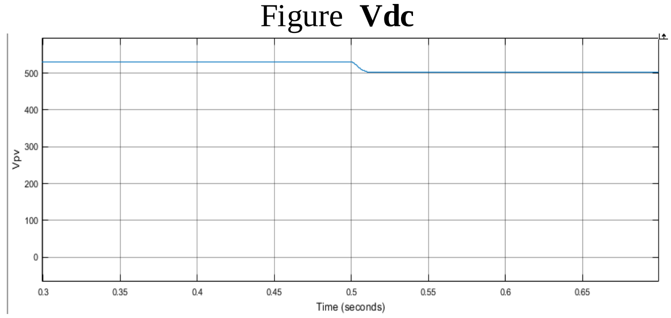


Figure **Vpv**

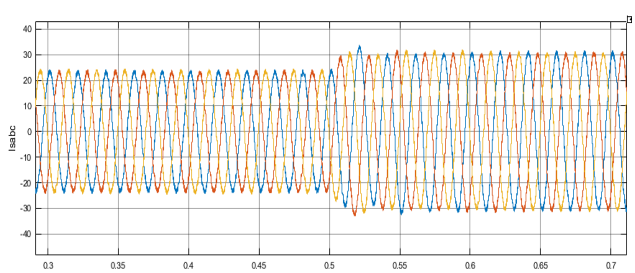


Figure **Isabc**

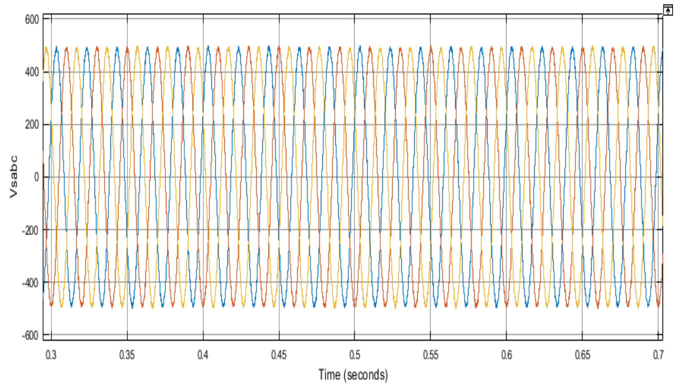


Figure **Vsabc**

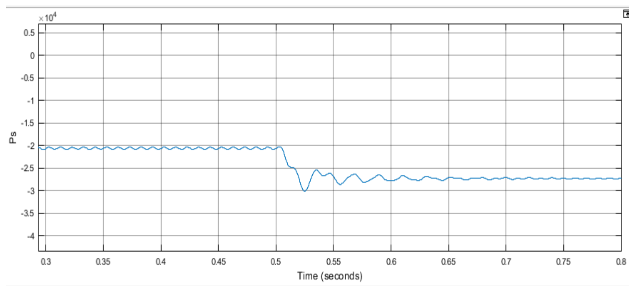


Figure **Ps**

Case_b

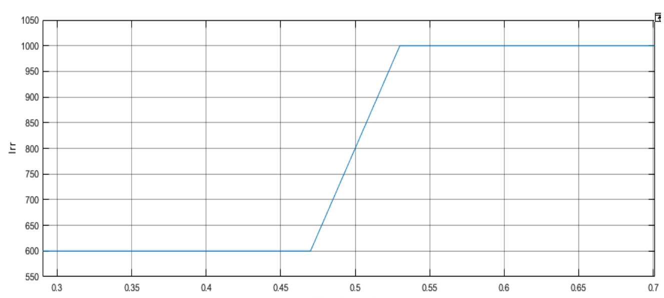


Figure **Irr**

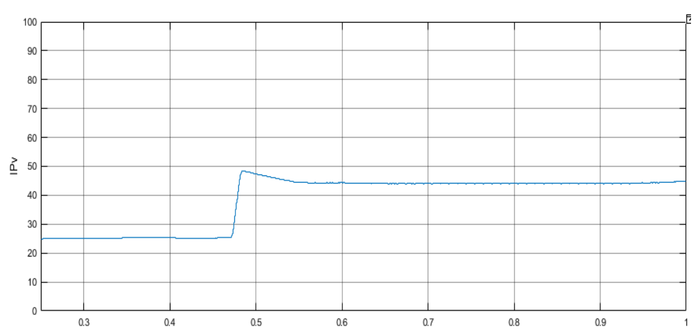


Figure **Ipv**

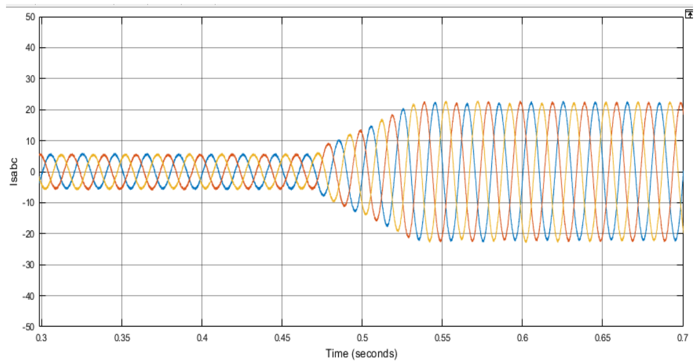


Figure **Isabc**

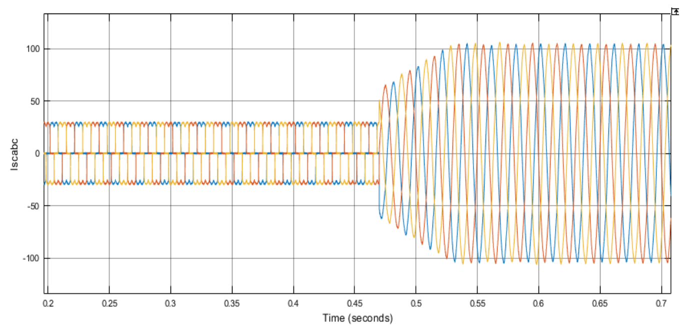


Figure **Iscabc**

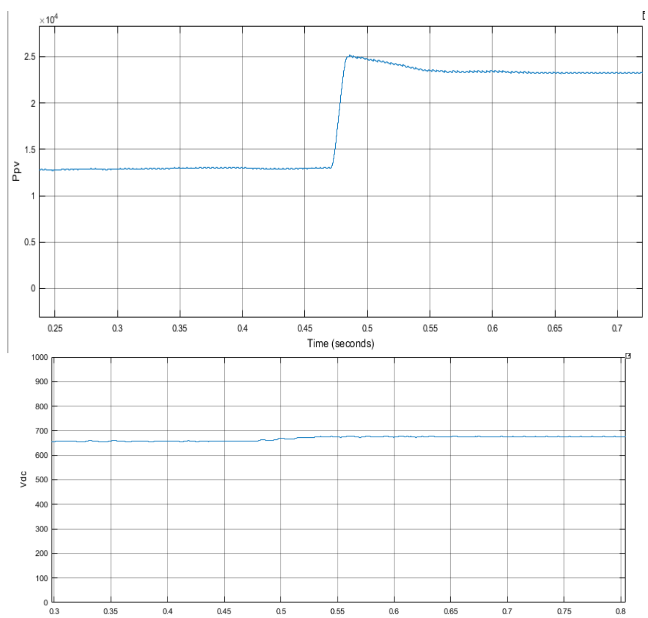


Figure **Vdc**

CONCLUSION

With an INC-based MPPT algorithm, an AFLL control was implemented on a double-stage three-phase grid-connected PV array system. The fundamental component of load has been extracted by AFLL.Even in the presence of dc offset and voltage, current flows efficiently. Distortion, voltage unbalance, and harmonics distortion are all examples of distortion. The controller's response is robust, and the system performs well in grid-adverse situations. The power quality of the grid improves during load unbalancing, insolation variation, and also during grid adverse conditions such as dc offset, grid faults, voltage distortion, voltage unbalance, and voltage swell/sag.

Future scope:

The work in this thesis is limited to PI Controller. With others, Fuzzy, Fuzzy PI, ANFIS controllers are used for tuning of PI controller.

REFERENCES

[1] R. Yacamini, “Power system harmonics: Part 3. problems caused by distorted supplies,” Power Eng. J., vol. 9, no. 5, pp. 233–238, Oct. 1995.

[2] A. Boži˘cek, J. Kilter, T. Sarnet, I. Papi˘c and B. Blaži˘c, “Harmonic emissions of power electronic devices under different transmission network operating conditions,” IEEE Trans. Ind. Appl., vol. 54, no. 5, pp. 5216– 5226, Sep./Oct. 2018.

[3] E. A. Cano-Plata et al., “Hybrid simulation of power quality assessment: an application for power ground grid in arc furnace systems,” IEEE Trans. Ind. Appl., vol. 52, no. 3, pp. 2648–2653, May/Jun. 2016.

[4] K. H. Sueker, “Comments on “Harmonics: The effects on power quality and transformers, IEEE Trans. Ind. Appl., vol. 31, no. 2, pp. 405–406, Mar./Apr. 1995

[5] M. F. McGranaghan, “Quantifying reliability and service quality for distribution systems,” IEEE Trans. Ind. Appl., vol. 43, no. 1, pp. 188–195, Jan./Feb. 2007.

[6] H. Heyge and G. W. Massey, “Discussion of "Power distribution system design for operation under non sinusoidal load conditions [with reply],” IEEE Trans. Ind. Appl., vol. 31, no. 5, p. 970, Sep./Oct. 1995.

[7] B. Singh, A. Chandra and K. Al-Haddad, Power Quality: Problems and Mitigation Techniques, Hoboken, NJ, USA: Wiley, 2015.

[8] A. Yazdani et al., “Modeling guidelines and a benchmark for power system simulation studies of three-phase single-stage photovoltaic systems,” IEEE Trans. Power Del., vol. 26, no. 2, pp. 1247–1264, Apr. 2011.

[9] M. A. G. de Brito, L. Galotto, L. P. Sampaio, G. D. A. E Melo, and C. A. Canesin, “Evaluation of the main MPPT techniques for photovoltaic applications,” IEEE Trans. Ind. Electron., vol. 60, no. 3, pp. 1156–1167, Mar. 2013.

[10] L. Costanzo, A. Lo Schiavo, and M. Vitelli, “Design guidelines for the perturb and observe technique for electromagnetic vibration energy harvesters feeding bridge rectifiers,” IEEE Trans. Ind. Appl., vol. 55, no. 5, pp. 5089–5098, Sep./Oct. 2019.

[11] M. A. Elgendy, B. Zahawi, and D. J. Atkinson, “Assessment of perturb and observe MPPT algorithm implementation techniques for PV pumping applications,” IEEE Trans. Sustain. Energy, vol. 3, no. 1, pp. 21–33, Jan. 2012.

[12] P. Kanjiya, B. Singh, A. Chandra, and K. Al-Haddad, “SRF theory re visited” to control self-supported dynamic voltage restorer (DVR) for unbalanced and nonlinear loads,” IEEE Trans. Ind. Appl., vol. 49, no. 5, pp. 2330–2340, Sep./Oct. 2013.