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Design and Performance of Single Stage Three Phase Solar Photo Voltaic using CTF-UPQC

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Abstract—An algorithm is necessary for high performance, reliable and secure control in three phase solar photovoltaic cell. Three phase single stage solar photovoltaic is designed and analysed in this paper by using control triangular function unified power quality conditioner (PV-CTFUPQC) technique. By using PV-CTFUPQC technique, the functioning of three-phase single stage solar photovoltaic can be improved. To produce fundamental output, PV-CTFUPQC maintains Root mean square (RMS) but in the proposed control RMS block is not needed. By using MATLAB/Simulink platform, three phase solar photo voltaic is designed and simulated. The proposed system function is validated on developed laboratory model. The generation of clean energy and enhancement in quality power are provided by proposed system.

KEY WORDS: Quality power, shunt compensator, series compensator, UPQC, Solar Photo Voltaic, MPPT (Maximum power point tracking), triangular function unified power quality conditioner (PV-CTFUPQC).

I. INTRODUCTION

In the present days energy development is a key factor in the researches and mostly used energy resources are hydro, solar and wind. Among these, least environmental footprint present in the solar. To extract the solar energy solar photovoltaic panels the well knownequipments in present days. The non linear relation present between voltage and current in the solar photo voltaic array that means ideal current source or ideal voltage source are can't be approximated. With the semiconductor technology increment, penetrations of power electronic loads are increased [1]. Adjustable speed drives, computer power supplies and switched mode power supplies are the example of electronic loads. Good efficiency and non linear currents produced in these loads.

In distribution systems, at the point of common coupling voltage distortion is occurred due to non linear currents. Due to fixing of photo voltaic systems in commercial buildings and small apartments clean energy generation has to be increased.

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In weak distribution systems penetration of PV energy sources increased causes problems of quality of voltage are voltage swags and swells [2]. Due to the voltage quality problems, increased heating of capacitor banks, triggering of electronic systems, and false tripping of power electronic systems can be occurred. Modern distribution system faces the major problem which is issue of power quality at grid side and load side.

Recently small signal models of Photo voltaic systems are to be constructed which includes various MPPT algorithms. Linearised model of small signal is not available in the method of incremental conductance and it is algorithm of tracking. To characterise dynamics of incremental conductance based MPPT process, existing methods are used. Based on the logic flowchart representation of algorithm, the method of dynamics of incremental conductance was implemented on MATLAB. However these models are complex to design and does not gives stability or robustness analysis. Due to growth in power quality requirement and clean energy, multifunctional system is needed to improve the power quality and clean energy generation.

For SPV grid connection and MPPT, utilize the single stage three phase systems. There are lot of techniques were proposed they are compensation of reactive power by using direct reactive power theory and triple phase grid interfaced Solar photo voltaic system. Functions of static compensator (STATCOM) performed by grid connected solar PV system and Hyo-RyongSeo proposed the three phase system which is an active power filtering [3]. For harmonic compensation, this system uses the SRFT (synchronous reference frame theory). By using DSTATCOM (distribution static compensator) active power filtering can be obtained. Active filtering, load balancing and voltage control are provided by distribution static compensator. The manage strategies for DSTATCOM and different circuit configuration were implemented. For the purpose of voltage control, SPV penetration was designed by using DSTATCOM.

Three phase multifunctional solar energy renovation system was implemented it is replaced for quality issues of load side power quality. By using active power filtering capability, single phase solar PV has been designed. Many research works done on clean energy generation by using filtering of shunt active. For regulation of load voltage, shunt active filtering maintains the capability, it is known by the injecting reactive power [4]. PCC voltages can't be regulated by shunt active filtering and grid current unity power factor does not be maintained.

Recently the utilisation of series active filters was designed in the applications of commercial building and small apartments due to stringent requirements of the voltage quality for some electronic loads.

Solar photovoltaic system has been implemented with dynamic voltage restorer. As compared to the series active filter and shunt active filters, unified power quality conditioner contains shunt compensator and series compensator performs regulation load voltage and the grid current can be maintained. The implementation of Photo Voltaic array using UPQC gives the universal active and clean energy generation. The solar PV with UPQC contains different advantages like protecting critical loads from grid side disturbances and improvement of power quality of the grid than the conventional grid connected inverters [5]. There is an interest in the UPQC due to the increment on distribution generation and microgrids.

In this paper, three phase PV-CTFUPQC is designed and analysed. Harmonic detection technique is a conventional CTF method. PLL and RMS blocks are used in this technique. This causes response could be slow and larger sampling rate. In this paper an advanced CTF control is implemented, complex blocks are not used in this control and fast response will be provided and reduction in sampling rate. Another advantage of this control is easy to implement and very simple.

The proposed system contains some advantages those are

- It provides improvement in quality of power and generation of clean energy.
- Upgrading in quality of current and voltage.
- Under different dynamic conditions are load unbalance, irradiation variation and voltage swells/sags, proposed system can be stable.

Under the steady state situations and dynamic conditions, proposed system performance can be analyzed by using software of Matlab/Simulink. Developed system performance is proved in various circumstances in distribution system like load unbalance, irradiation variation, and voltage swells/sags.

II. SDUAL PURPOSE SINGLE-STAGE GRID CONNECTED SOLAR PHOTO VOLTAIC SYSTEM

For fundamental extraction, ILST (improved linear sinusoidal tracer) was implemented. After that for power quality improvement ALST (adaptive linear sinusoidal tracer) was also implemented. Adaptive linear sinusoidal tracer is implemented by using quality of real power injected into the grid. From PV array minimum power extracted by SPV system implementation and minimum power given to the three phase distribution system. From PV strings power extracted by using incremental conductance MPPT algorithm.

In existed system grid connected solar PV energy conversion technique was implemented in which balancing of grid currents, functions of harmonics mitigation and correction of power factor is performed. The utilization of existing distribution system can be efficient and effective by grid current's balancing, hence it is an important characteristic. Depends on ILST algorithm, for grid interfaced system the algorithm is utilized. The advantages of ILST control technique are fast convergence, simple control and physical significance of internal parameters. However researchers said that three phase single stage systems works as filter of active power on hazy days and on sunny days it works as solar energy conversion system.

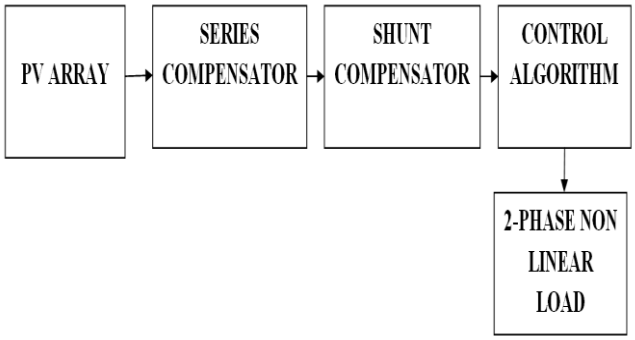

Fig. 1: DUAL PURPOSE SINGLE-STAGE GRID CONNECTED SOLAR PHOTO VOLTAIC SYSTEM

Ripple filter, VSC, solar PV string and interfacing inductors are presented in this system. To match required power rating series parallel combination of small photovoltaic modules are used in PV strings. The dc bus of VSC connected with PV string as parallel. Three phase distribution system is connected with solar PV conversion system. Loads are connected to the nature either be linear or non linear and those are replaced by VSC of solar PV system. Balancing, Grid currents, Harmonics elimination, correction of power factor and functions in MPPT are performed by VSC and proper control also provided. Switching harmonics are filtered by ripple filters and interfacing inductors.

There are two subdivisions in control algorithm, one is MPPT it decides the reference dc link voltage and other one is achievement of current control of VSC. VSC contains control functions such as harmonics mitigation, grid currents balancing and correction of power factor. By using proportional integral controller, MPPT algorithm decides the Photo voltaic array voltage at reference voltage. Extract the load current fundamental components by using algorithm of ILST control. The usage of sample and hold logic and zero cross detector, load currents active power components are extracted. In VSC the loss component will be determined and to estimate reference grid currents all components are integrated.

Unity power factor inhibited by VSC and Grid currents are balanced. To coordinate the currents feeded into the grid, unit templates are used which are obtained by PCC voltage. If grid currents maintain UPF then exchanging is done on grid. Within the loads, solar Photo Voltaic, and the grid net active power should be balanced. Net currents over the grid are approximated and designed like grid currents reference based on this topic. To manage the grid currents use the approach of indirect current control. The sensed currents of grid are compared with reference currents of grid and for the control of current, current controller is utilized.

III. SINGLE STAGE THREE PHASE SOLAR PHOTO VOLTAIC USING CTFUPQC

The below figure (2) represents the **block architecture of developed system**. For the presentation of three phase single stage system, photo voltaic control triangular function unified power quality conditioner (PV-CTFUPQC) is proposed. Series and shunt connected voltage compensators are used in PV-CTFUPQC, which are connected end-to-end with familiar DC link. The power extracted from PV array by the shunt capacitor and dual function is performed except replacing of load current harmonics. To improve the performance of PVCTFUPQC extracts the load active components using moving average filter based improved synchronous reference frame control. The problems of power quality on grid side are grid voltage swell/sags, compensated by series compensator. During the sag and swells conditions the compensator transmit same voltage/difference of voltage sign with PCC.

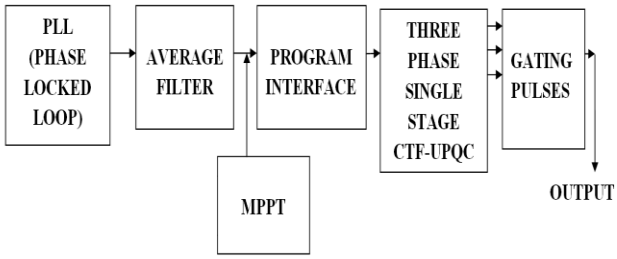

Fig. 2: SINGLE STAGE THREE PHASE SOLAR PHOTO VOLTAIC USING CTFUPQC

At the side of load, shunt compensator is connected. The DC link of CTFUPQC combined with solar photo voltaic array using reverse blocking diode. The grid voltage swells/sags are compensated by series compensator and it is operated in voltage control mode. By using interfacing inductors the grid combined with series and shunt compensators. To give the generated voltage into grid, series injection transformer is used by series compensator. Due to the switching action of converters, harmonics are generated which are removed by ripple filters. The bridge rectifier along with voltage load is used in load which is used in nonlinear load.

Proper sizing of solar photo voltaic array, voltage level of DC link and capacitor of Dc link are the first step in the designing of PV-CTFUPQC. Shunt compensator maintains the output of peak power from Photo Voltaic arrangement when it should be sized except for harmonics of current and load current reactive power. The photo voltaic array is sized and MPP voltages are up to voltage of DC link when DC link is combined with Photo Voltaic array in CTFUPQC. Photo voltaic array send the power into grid and photo voltaic array provides the load active power in normal conditions.

$$v_a = \frac{2v_{ab}+v_{bc}}{3} ; v_b = \frac{-v_{ab}+v_{bc}}{3} ;$$
$$v_c = \frac{-v_{ab}-2v_{bc}}{3} \ldots\ldots\ldots . \quad (1)$$

Here Vt means terminal voltage amplitude. Quadrature unit and in-phase templates are approximated like

$$V_t = \sqrt{\frac{2}{3}(v_a{}^2 + v_b{}^2 + v_c{}^2)} \quad (2)$$

The compensators of Series are the important sub systems in PV-CTFUPQC system. Reactive power of load and problems of quality of load power are compensated by shunt compensator. The supplying of power solar PV array is the additional function performed by shunt compensator in PVCTFUPQC. By using MPPT algorithm, from the Photo Voltaic array the power is extracted by shunt compensator. The problems of power quality of grid side are voltage swells/sags which affect the load and load is protected by series compensator by sending same voltage with the grid voltage. The compensator for shunt operated at highest power point and this power extracted from photo voltaic arrangement by shunt compensator. The reference voltage generated by MPPT algorithm which is used for the DC link in PV-CTFUPQC. Peturb and observe algorithm and algorithm of incremental conductance are the examples of MPPT algorithms. To implement maximum power point algorithm, Peturb and observe algorithm is used. PI controller is used to maintenance of DC link voltage at the reference point.

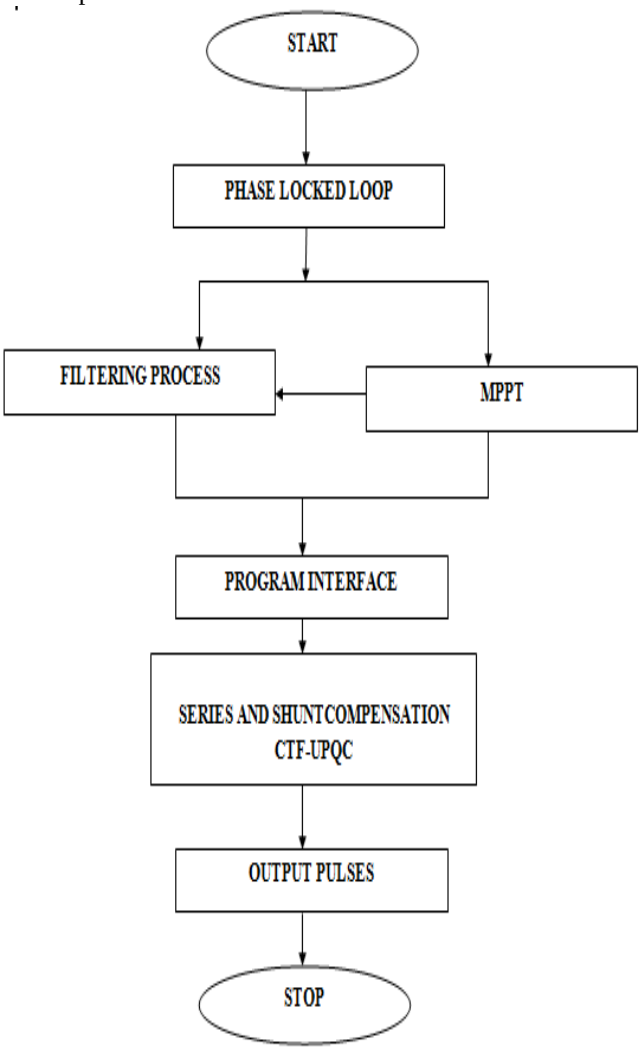

Fig. 3: FLOW CHART OF THREE PHASE SOLAR PHOTO VOLTAIC USING CTFUPQC

The Optimal compensation, same phase compensation and presage compensation are the control strategies of compensator for series. In the proposed system series compensator maintains injected same voltage like grid voltage; causes series compensator provides minimum injection voltage.

By using PLL, the PC voltage fundamental components are extracted; the reference axis in dq-0 domain is obtained by PLL. In PCC voltage by using frequency and phase information, generation of reference load voltage is done. D-q-0 domain converted with load voltages and PCC voltages. In the voltage of load reference, d-axis represents the voltage peak load reference when reference voltage is same as PCC voltage.

Zero is maintained in the component of q-axis. On behalf of the series compensator, the voltage of reference is given by the difference between PCC voltage and load reference voltage. The voltage of Actual series compensator is given by dissimilarity between voltage of PCC and voltage of load reference. To generate reference signal the voltage difference between series compensator and reference feed to PI controllers. For the series compensator, gating signals are generated by passing of converted ac domain passed over the PWM (pulse width modulation).

Root mean square blocks (RMS) are used in control triangular function because it provides output of fundamental signal. But CTFUPQC does not maintain RMS block. RMS and PLL blocks are the complex blocks causes computational time is increased and mission for low end processors is increased. So that proposed system gives better efficiency.

IV. RESULTS

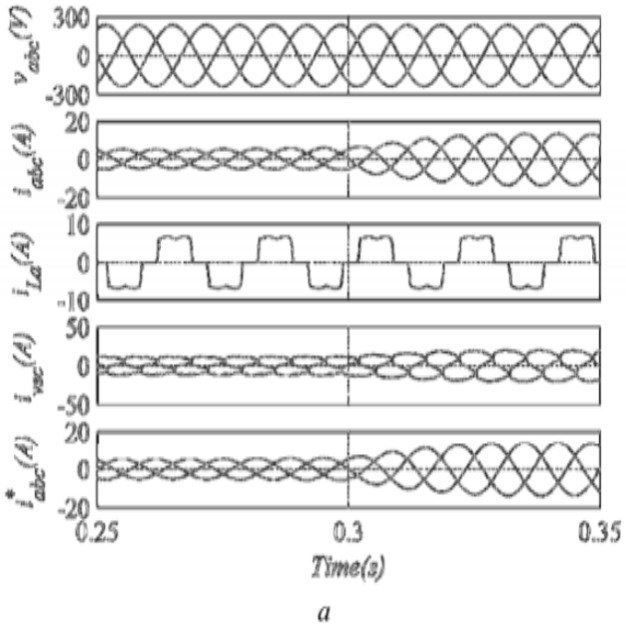

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Fig. 4: DYNAMIC PERFORMANCE UNDER VARIABLE SOLAR ISOLATION

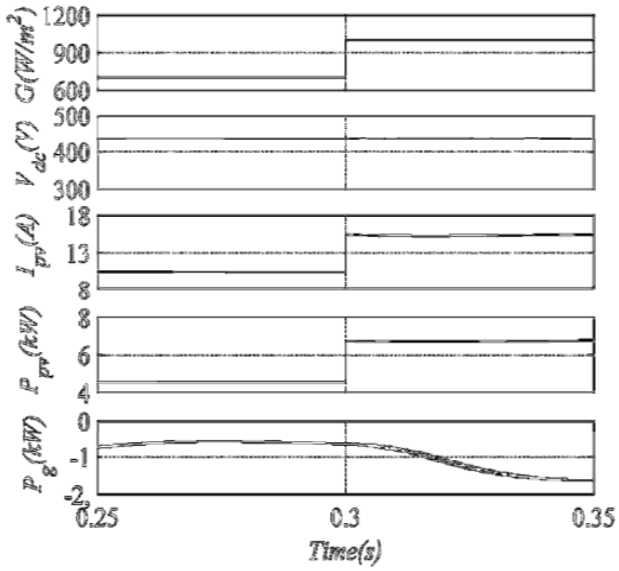
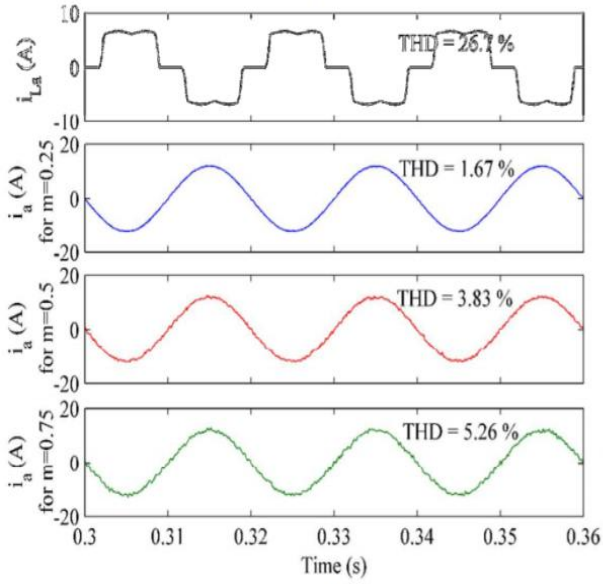


Fig. 5: POWER EVALUATION

Time (s)

c



d

Fig. 6: PERFORMANCE EVALUATION AND COMPARATIVE ANALYSIS

V. CONCLUSION

The three phase single system PVCTFUPQC is designed and its dynamic performance has analyzed beneath the grid voltage swells/sags and variable irradiation. Under the circumstances of voltage swells/sags, variation of irradiation and load unbalance, the proposed system maintains stable condition. There is an improvement in d-q control performance in the condition of load unbalanced by using moving average filter. For modern distribution system, PV-CTFUPQC is the better solution by combining of improvement in power quality with distributed production. The features of this system are fast responses are obtained, easy to implement and it is very simple.

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