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LOAD BALANCING IN PRIMARY DISTRIBUTION FEEDERS BY COMBINATION OF RENEWABLE ENERGY SOURCE AND VOLTAGE SOURCE INVERTER

Metkari Vishal T.,
Department of Electrical, Sanjeevan Engineering & Technology Institute , Panhala,

Naik Yogesh R.,
Department of Electrical, Sanjeevan Engineering & Technology Institute , Panhala,

Abstract— In distribution automation system configuration the distributed generation directly connected to primary distribution system. To achieving the all total generation of PV the radial network converted into mesh or loop by connecting loop power controller at the receiving end of primary distribution system. The loop power flow controller has capable to control power flow between two distribution feeders by maintaining active and reactive power. The loop power flow controller control active power by changing phase shift and reactive power by changing voltage ratio. In these paper control algorithm in MATLAB is used to control voltage ratio and phase shift of LPC, and results shows how loss on distribution system is minimized.

Keywords- ; loop power flow controller, Photovoltaic generation, feeder, load balancing

I. INTRODUCTION

Now the World facing problem of global warming and energy consumption both these problem can be minimize using renewable energy sources .The solar power on earth is 10^{16}watt which is vary huge. So that proper new technology required to integrate renewable energy source into power system.

The balancing load on distribution system is the switching operation that eliminates overloading on distribution system. Load balancing can he obtained by reconfiguring the distribution feeders and reallocating load currents among the feeders and transformers. By properly performing the switching operation, the power demand of the service zones can be shift from the heavily loaded transformers/feeders to the lightly loaded transformers/feeders. So that the distribution system will become more balanced and the risk of overloading can be reduced. The problem to use switching operation in distribution system that high voltage surges , how much time it should be in operating condition is defined by using membership function[3] and renewable energy source do not use . The balancing load on distribution system required for

- It reduces demand during critical load period.
- It must have an acceptable cost ratio.
- It must operate an acceptable reliability level.
- It must provide benefit to the consumer by reducing cost.

However, it's difficult to achieve load balancing on distribution feeder when intermittent PV generation inter connected between feeders, because reveres power flow though the system when generation is high. To maintain the reverse power flow through the system the new technology is necessary.

The balancing load on distribution feeder is explained with the help of branching exchanging method [1]. In fuzzy reasoning approach membership function for feeder, transformer, lateral and switches is given for balancing load on feeder and transformer together [3]. Qin zhon have studied two feeder reconfiguration algorithms for the purpose of service restoration and load balancing in a real-time operation environment[2] .M.saradarzadeh and S. Farhangi have studied(D-SSSC), Distribution static synchronous series compensator enable to control reverse power flow through distribution feeders and avoid congestion in the network[12]. mahashide hojo use LPC in between distribution feeder for maintaining fault current [13].

In this paper control algorithm used to control power flow through loop power controller by generating gate pulses for VSI. The LPC used to balancing load on distribution feeder due to those losses is reduced and reliability of distribution system increases.

II. EQUIVALENT ELECTRIC CIRCUIT OF PHOTOVOLTAIC CELL

Fig .1 shows equivalent circuit of a PV cell. It contain current source, diode, series resistance and shunt resistance Current flow through load is given as

$$I = I_{-ph} - I_{-s}\left(\exp\frac{q(V+R_s\ I)}{NKT} - 1\right) - \left(\frac{V+R_s\ I}{R_{sh}}\right) \quad (1)$$

$$I_{-ph} = [\ I_{sc} + K_i(T-300)]\beta/1000 \quad (2)$$

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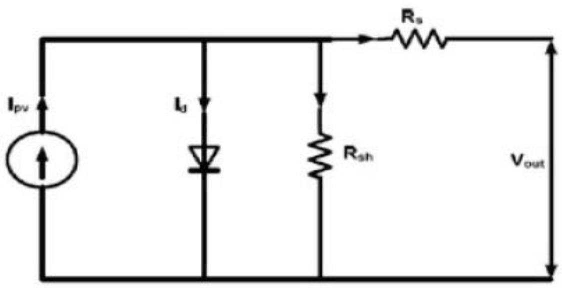

Fig. 1. PV Cell Equivalent Circuit [9]

In this equation, $I_{-ph}$is the photocurrent,I_{-s} is that the reverse saturation current of the diode, q= 1.602×10^{-9}C, is that the electron charge, V is that the voltage across the diode, K = 1.3806503 × 10−23 J/Kis the Boltzmann' s constant, T is that the junction temperature, N is that the quality issue of the diode, K_i=0.0017 A/◦C is that the cell's short circuit current temperature coefficient β is the solar radiation (W/m2) and $R_s$and $R_{sh}$are the series and shunt resistors of the cell, respectively[9].

III SIMULATION MODEL OF PV ARRAY

The simulation of PV array contains 553 PV cell and output voltage of each PV array is 380v and produce power is 19.54KW. These power injected into distribution feeders with the help of following equipment.

1) DC-AC convertor; This block contain voltage regulator, universal bridge, the voltage regulator generate delay reference signal these signal given to
Universal bridge and bridge convert dc voltage into ac voltage.

2) Transformer; The generally step up transformer with star connected winding and 2MVA rated capacity is used which step up 380v ac into 22.8or 11kv and maintain synchronization.

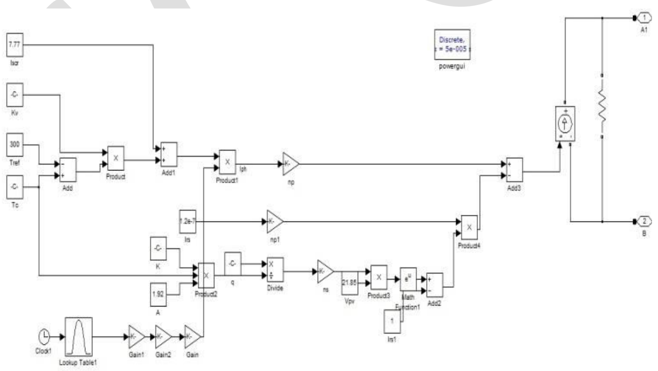

Fig.2. Simulation of PV Array

The fig .2 shows simulation Of PV array in this series resistance is neglected and parallel resistance value taken as large as possible fig .3 shows output of PV array.

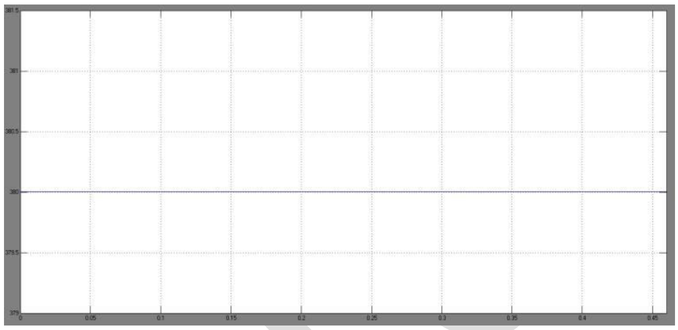

Fig .3. Output Voltage of PV Array

IV. A LOOP POWER FLOW CONTROLLER BY USING VSI

The loop power flow controller consist of series connected voltage source inverter which is constant voltage source and bidirectional current control device, used to control power flow through two distribution feeders to balancing load on distribution system and fault current limitation. The following advantages of LPC used in distribution system.

1) It provides open access to the distributed power supply.
2) It provides flexibility to the distribution feeder.
3) It provides protection to the distribution system.

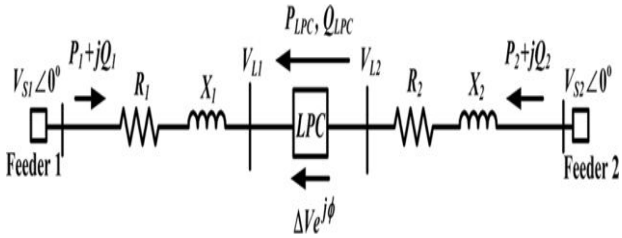

Fig.4. Model of Distribution Feeders With LPC [6].

The figure.4 show how LPC is connected in between two distribution feeders and maintain active power and reactive power. The LPC required proper control algorithm to flow dependent current through the feeders by changing voltage ratio and phase shift. The structure of LPC show in fig.5 which contains voltage source inverter, pulse width modulation, sine wave generator and control algorithm. The VSI is used because output is constant and current flow bidirectional. The PWM technique used to control output of VSI, in this paper SPWM is used because it produces constant amplitude and frequency output voltage. Then control

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algorithm generate required voltage ratio and phase shift according to load on feeders and PV generation, that output multiply with sine generator output and generated output given to the input to PWM.

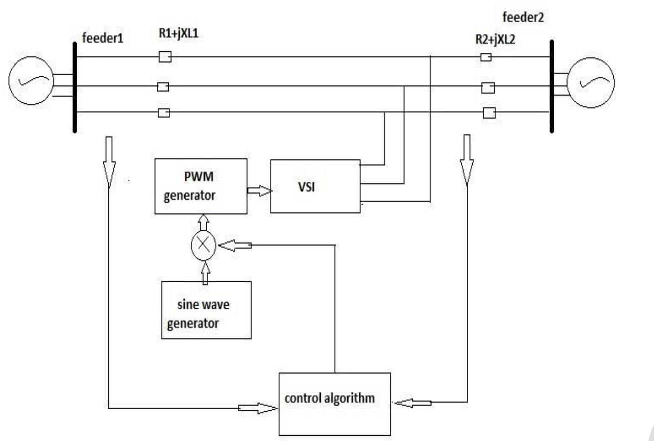

Fig.5. Structure of LPC [6]

V. CONTROL MODES OF THE LPC

A. Power Flow Control by using LPC

The LPC acts like variable reactor so as to regulate power flow through distribution feeders. The LPC detect variable voltage across inductor and according to it induce voltage into distribution system for load balancing. By using voltage and current phasers the output can be represent as.

$$V_s = K.V_{Xs} = K(jX_s\ I_c) \qquad (1)$$

Where,
K= control gain, V_{Xs} = Voltage across inductor, I_c = Current flow through LPC
So with the variable rector KX_s the active power flow through LPC is

$$P_c = \frac{V_{s1}\ V_{s2}}{(K+1)X_s}\sin(\theta_{\delta 2} - \theta_{\delta 1}) \qquad (2)$$

Where, $V_{s1} < \theta_{\delta 1}$, $V_{s2} < \theta_{\delta 2}$ respective receiving voltages of each line when K≠-1 then LPC regulate power flow through the line.

B. Fault Current Limitation

The LPC also maintain fault current flow through distribution feeders by applying high inductance into distribution feeder, due to this thermal limit of distribution feeder is maintain.

VI. CONTROL STRATEGY

The aim of this control strategy is to control amplitude and frequencies of load voltage vg as shown in fig.6. The control strategy show the inner is current control and outer is voltage control loop. The inner current control loop measure inverter current i_l and compare with $i*_l$ and error signal produce this signal produce output $v*_{sw}$ .The $v*_{sw}$ or voltage ratio and phase shift used to control input of PWM and PWM control VSI output.

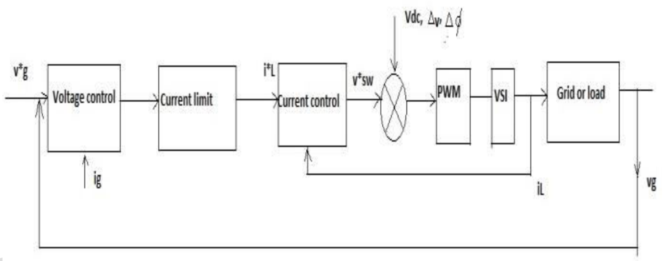

Fig. 6. VSI control scheme [6]

A. Control Algorithm for control voltage and phase shift

The LPC control algorithm for balancing load on distribution feeder by maintaining active and reactive power flow, that obtained by proper voltage ratio and phase shift.

$$\left.\begin{aligned} P_{LPC} &= \frac{P1-P2}{2} \\ Q_{LPC} &= \frac{Q1-Q2}{2} \end{aligned}\right\} \qquad (1)$$

If the branch impedances of Feeder 1 and Feeder 2 are (R_1,X_2) and (R_2,X_2) respectively, Then.

$$\left.\begin{aligned} R_t &= R_1+R_2 \\ X_t &= X_1+X_2 \end{aligned}\right\} \qquad (2)$$

The load balanced can be obtained by assuming VL1=1<0 and

$$|V'L_2| = \sqrt{(1 + P_{LPC}R_t + Q_{LPC}X_t)^2 + (P_{LPC}X_t - Q_{LPC}R_t)^2} \qquad (3)$$

The incremental terminal voltage ΔV and phase shift ΔØ are therefore calculated as follow

$$\Delta V = |V'L_2| - 1 \qquad (4)$$

$$\Delta\Phi = \tan^{-1}\frac{P_{LPC}X_t - Q_{LPC}R_t}{1+P_{LPC}R_t+Q_{LPC}X_t} \qquad (5)$$

VII. PULSE WIDTH MODULATOR

In PWM technology first generate triangular wave and compare it with dc voltage which adjust to control ON and OFF time. When triangular wave above the demand wave than

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output is high and when triangular wave below the demand wave than output is low.

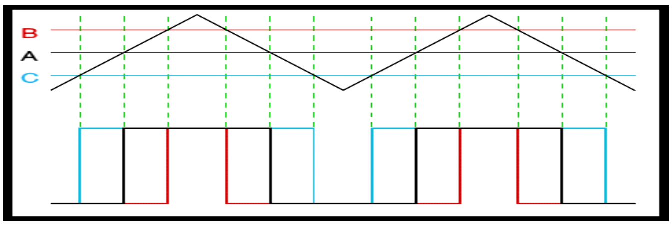

Fig.7. Comparison of carrier and reverence wave [11]

VIII. SIMULATION:

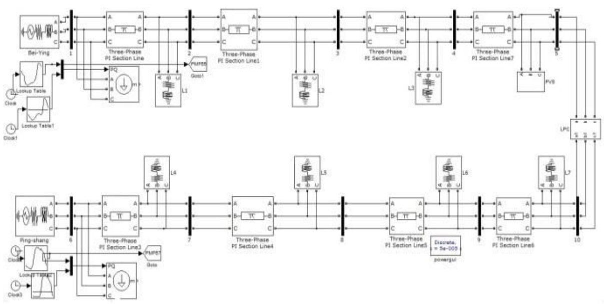

Fig.8. Main System

The fig.7 show two distribution substation the total load on two distribution system is 161MW. The load on upper substation is 79.25MW and load on lower substation is 82.375MW. The load on lower substation is high so that power loss is high by using Netwon –Raphson load flow analysis loss on total system is 3.256MW. When LPC connected at the receving end of both the substation feeders then the the total loss of system 2.8 MW by trasfaring load form heavly loaded feeder to lightly loaded feeder as show in fig 12.

IX. RESULTS:

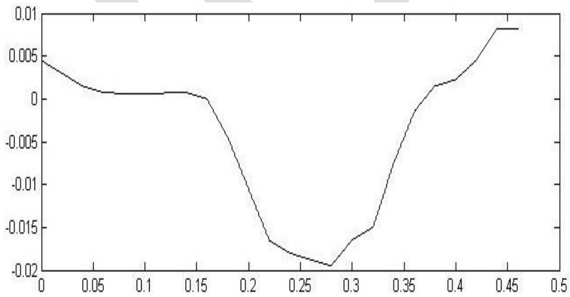

Fig.9. Voltage Ratio of LPC

The fig.8 and fig.9 show the voltage ratio and phase shift of LPC these are change according to change in resistance and reactance of distribution feeders according to loads . The fig. 11 show that PV generation without LPC then there is problem to maintain proper PV generation in lightly loaded feeder because reverse power flow through the circuit. The fig.13. shows there is considerable amount of loss reduction by using LPC

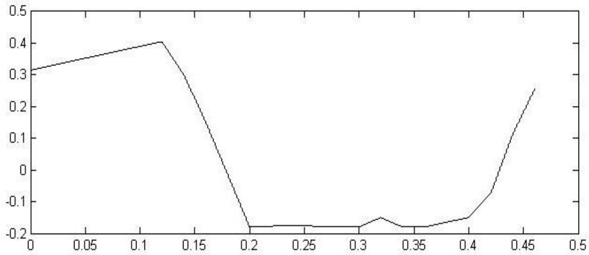

Fig.10. Phase Shift of LPC

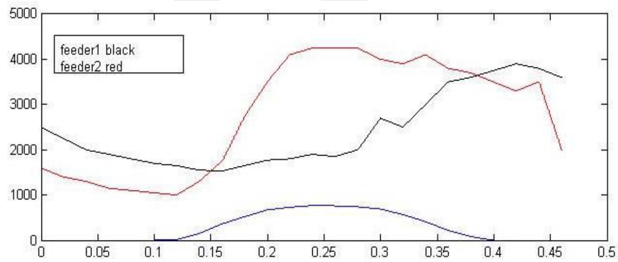

Fig 11. Load on distribution feeders

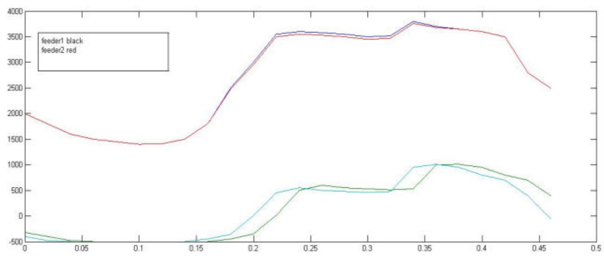

Fig. 12. Load Balancing Using LPC and PV Generation

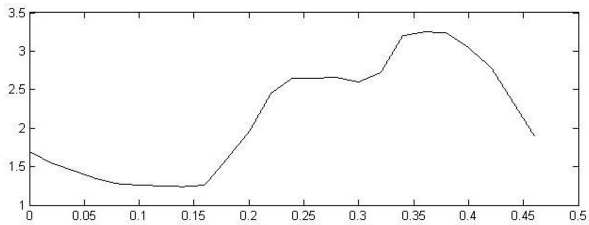

Fig.13. Loss Reduction Using LPC

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X. CONCLUSION

In this paper focuses on loss reduction on distribution system and maintain reliability at the overloading. If the switching technique is used than there is problem to maintain switching surges and to maintain proper load balancing between the feeders. so we use LPC technique to reduces power losses and balancing load on distribution feeders. Load on distribution feeders balanced by proper placing loop power flow controller at the receiving end of distribution feeders. The control algorithm used to proper power flow through distribution system with the help of loop power flow controller. The LPC adjusted the voltage ratio and phase shift for properly inject active power and reactive power to the distributed feeders. Then this system also helpful for renewable energy sources connected in distribution system.

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