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Active Power Factor Correction

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Abstract**—** Lower in Power Factor of electrical equipment's will draws high current from supply power. The effect of this is affected by impedance of electrical equipment. Power factor correction of boost converter is done by using predictive control strategy. In this project predictive control algorithm is presented based on this algorithm all of the duty cycles required to achieve unity power factor in one half line period are calculated in advance by proportional Integral (PI) controller, the simulation results show that the proposed predictive strategy for PFC achieves near unity power factor. The power factor and input current distortion are analyzed using with control and without control techniques. Simulation results are shows that the power factor is higher than 0.99, and current total harmonics distortion (THD) is smaller than 20% under full load condition. In this project is how impedance of electrical equipment affects the power factor of electrical loads, and then distributed power as the whole. This project is important to verify the right action to increase low power factor effectively for electrical energy efficiency concern.
Keywords—AC-DC Converter, PI Controller, Predictive control algorithm

I. INTRODUCTION

Conventional AC-DC converters are widely used in various applications due to the advantage of high efficiency. These converters draws a non- sinusoidal input ac current which leads to low power factor and injection of harmonics into utility lines. The harmonic currents the converter generates distort the ac line voltage and cause power disturbances. In order to reduce harmonics active and passive filters are being used. The passive filter includes the use of resistors, inductors, and capacitor elements at load side. But these have the disadvantages of low efficiency and high cost. Hence active techniques have gained more importance, which includes use of power electronic switches like IGBT, MOSFET, GTO etc. The high RMS line current also places a high stress on the bridge rectifier and the energy storage capacitor. With increasing demand for more power and better quality, power factor correction becomes an integral part of a switching power supply. Therefore the power factor correction circuits are getting popular and the regulation power range is getting lower. Power factor correction technique has been widely used in AC to DC switching mode power conversion system. PFC can reduce the harmonics of line current, losses and improve power factor by unity power factor control to meet the requirement of international standards, increase the efficiency and capacity of power systems, and reduce customers" utility bills. Numerous methods have been proposed in recent years to achieve unity power factor for the switch-mode power supply. Among them, the boost converter with constant switching frequency is the most popularly used topology. The advantages are:

i) The input current is a smooth waveform, resulting in much less EMI and therefore reduced input filtering requirements

ii) Current stress in the power switches is lower;

iii) The inductor current in the boost converter is the input current and is therefore easily Programmed;

iv) The dc output voltage is higher than the peak of the input voltage. In this paper, a new predictive control method of the boost PFC converter which improves the zero-crossing distortion is proposed. The proposed method changes switch on-time according to the magnitude of ac line voltage. The experimental results verify the excellent performance of the proposed method.

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Power factor (PF) is the ratio of Real power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA) or also known as demand. It will get by multiplying [kVA=V*A]. The result will be in kVA units.
Oommen and Kohler (2008) explored the advantages that can be accomplished by proper implementation of power factor compensation
Wanfeng et al [1]outlined the different methods for power factor correction and carried out an experimental case study to explore the areas which will be suitable for compensation
Pandey [10] proposed a novel single-phase power factor correction scheme based on parallel power factor correction concept which was described to be more efficient than convention two-cascade stage scheme

II. WORKING

A typical active power factor correction model setup is implemented using blocks from Simscape Electrical and Simulink. Let's look at the different elements of the model. AC source of 120V rms is connected to a diode bridge rectifier. This rectifier is connected to a digitally controlled boost converter and a resistive load rated at 400V. We have modeled the digital control algorithm in this subsystem named Controls. Cascaded control loop architecture is shown in Figure 1.The outer loop controls the load voltage and the inner loop controls the inductor current.
Our control algorithm computes a PWM signal that drives the MOSFET of the boost converter. We will work with the parameter values for inductance and capacitance already in our model, but it is important to note that we can easily change those values, run the simulation, and observe changes. Simulation model is used to choose optimal parameter values for passive components, but our focus here is on the digital control algorithm as shown in Figure 3. In this model, the PI gains for the controllers were set as initial guesses. These gain values [2] do not provide the best power factor correction. In this plot we see the line voltage in yellow and the line current in blue. The current waveform shows the presence of harmonics, which results in a poor power factor. We will therefore need to retune the controllers for a better power factor correction.
Workflow will be the following: first tune the inner loop to obtain the optimal PID gains for the current loop. With the inner loop tuned, tune the outer voltage loop to compute gains for voltage loop PI controller.
To do the tuning, we need to obtain a linear plant dynamics model. For the inner loop, we need to obtain dynamics from PWM duty cycle to inductor current. We will use Linear Analysis tool from Simulink Control design to do this. With this tool we can estimate the frequency response of the model by doing an AC sweep. We need to do this AC sweep around the appropriate operating point or bias point. To do the AC sweep we have to replace the AC voltage source with a DC source. This model has been set up to operate at its DC operating point with a DC voltage source of 120V and a steady state duty cycle of 0.72 [AT1] to maintain a constant DC output of 400V.
We can specify that we are interested in the dynamics from the PWM duty cycle to the inductor current by marking those signals as input and output linearization points respectively. The simulation reaches steady state at about ~0.15 seconds, so we will the start frequency response estimation at that time when the steady state has been reached. Next, we specify that we will inject the fixed step sine stream input with a sample time of 0.2 microseconds to the model. We set the frequency sweep range from 10Hz to 15kHz and the amplitude of the signal to 0.036 to ensure sufficient excitation within the operating range. We choose this signal amplitude to be small enough to not take us away from our operating point.We then start the frequency response estimation. The model is simulated and the plant frequency response is computed. We will export it to the MATLAB workspace to use for the PI controller tuning.In this next step we set up the current PI controller in the controls subsystem with the reference and the measured inductor current to operate in closed loop.

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Next, we tune the gains of PI controller block by pressing the tune button in the block dialog. This launches the PID Tuner that tries to automatically linearize the plant. Because in this model we have discontinuities such as MOSFETs and PWM [3] switching, the model cannot be linearized analytically. However, this is okay because this is exactly why we ran the frequency response estimation before. We can now simply point the PID Tuner to the estimated frequency response.

The PID Tuner uses this frequency response to compute PI gains to provide fast and stable closed-loop operation of the system. We can use the sliders to adjust the bandwidth and the phase margin. We will tune for the bandwidth of around 3.760 kHz and phase margin of 60 degrees to maintain a robust current reference tracking.We can now take the computed PI gains and update them in the PI block of our model. With the inner current loop tuned, we will repeat the process to tune the outer voltage loop. In the Controls subsystem, the constant block of 1 here represents the inductor current request. In our final model this signal will be computed by the outer voltage loop. So for tuning the outer loop, our input linearization point is this signal, and the output linearization point is the output voltage signal.

The simulation reaches steady state at around 0.4 seconds, so we will tell the Linear Analysis tool to start the frequency response estimation at around that time. We set the fixed step sine stream signal sample time to 0.2 microseconds with an AC frequency sweep range from 10Hz to 5kHz. The amplitude of the perturbation is set to be 0.1 to ensure sufficient excitation. We can now run the tool and compute the frequency response for tuning the outer loop.

Next, just like we did for the inner loop, we will set up the outer loop Controls subsystem with the Voltage PI controller, and start the tuning by launching the PID Tuner. Again, similar to how we did it for the inner loop, we import the previously estimated frequency response to compute the PI gains. The voltage loop is slower than the inner current loop, so we set the bandwidth to be around 55 Hz and keep phase margin at 60 degrees. With this chosen bandwidth, the controller will follow the reference voltage while rejecting the 120Hz oscillations of the rectified AC source.We then update the voltage PI Controller with the computed gains. To verify the performance in the nonlinear model, let's run a step change in the reference voltage. The simulation results show a robust controller performance.

Now let's switch the voltage source back to the original AC grid and run the simulation. We can see that the inductor current and output voltage profiles show good reference tracking. The line current drawn from the AC grid resembles a perfect sinusoid and is much better than the current profile we had before the controller tuning. We see a reduction of harmonics, thus providing a better power factor.

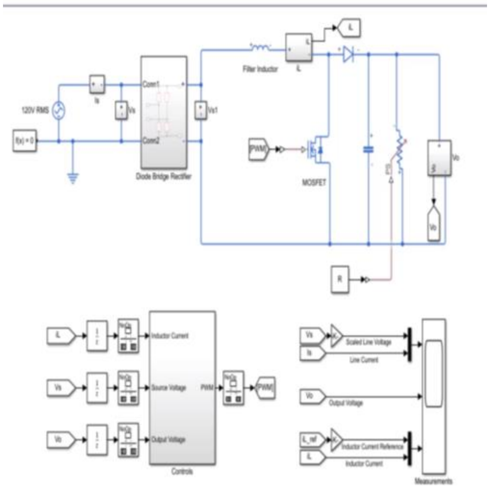

Fig.1:Circuit Diagram

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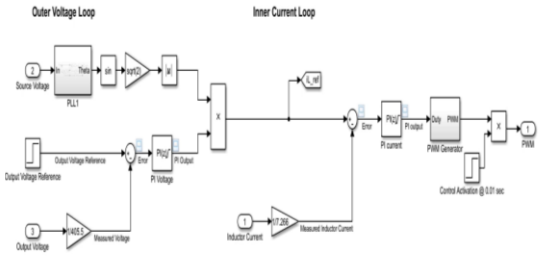
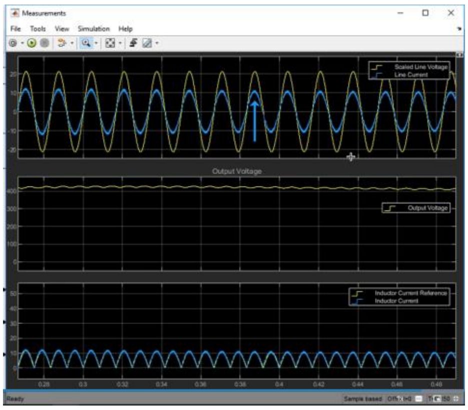


Fig 2. Control Circuit

III. SIMULATION RESULT



IV.ALGORITHM

Duty cycle is generated by implementing the duty cycle equation in the MATLAB programing. Step by step programing is given below. Flow chart is given in figure

- First the constant parameters like inductance value, switching frequency are initialized.
- The input voltage, output voltage and amplified error voltage are sensed and are embedded into the programing.
- The reference current is generated with frequency equal to input line frequency at the present instant. The reference current at next instant is generated at time value one sampling time greater than the present time.
- The duty cycle component is generated based on the derived equations.

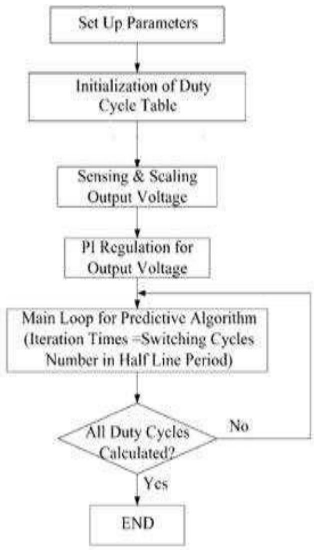


Fig.3:Software flowchart for predictive algorithm implementation.

V.ADVNATAGE AND DISADVANTAGE

Advantages:

1. Increase in efficiency of system and devices
2. Low Voltage Drop
3. Reduction in size of a conductor and cable which reduces cost of the Cooper
4. An Increase in available power
5. Line Losses (Copper Losses) I2R is reduced
6. Eliminate the penalty of low power factor from the Electric Supply Company
7. Power factor $\geq$ 0.95
8. Constant Intermediate voltage to drive the DC/DC converter, simplifies the requirements and the complexity of the DC/DC converter.
9. Small, light inductive components.
10. Wide range of input voltages, can work with 87Vrms – 266Vrms 47Hz-63Hz without switching
11. Greater flexibility and control

Disadvantage

1. Higher overall cost and complexity
2. Requires better filtering to prevent high frequency hash from getting to the line
3. Higher voltage components than would be required for a passive PFC

CONCLUSION

Power factor correction for without control technique and Predictive current control technique are developed and simulated in MATLAB/Simulink. The simulation results for the control techniques verified. Their performances for different input voltages and different loads are tabulated. From the results it is observed that predictive current control gives better power factor correction for different input voltages and different loads than that of without control technique.

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