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Power Quality Improvement in Power System with PMSM Drive

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Abstract: The main perceptive predicament in power system is power quality issue. Majority of the power system contamination is due to the presence of non-linear quality of loads. Increase in the usage of non-linear type of loads leads to rise in power quality issues and becoming serious crisis with time. A power quality improvement device for medium-voltage distribution network is developed, whose power unit and topology of charging circuit is designed and a fixed voltage slow closed loop control strategy is proposed in this paper.The simulation model and the results are analyzed using MATLAB/Simulink.
Keywords: power quality, closed loop, non-linear.

(1) Introduction

Power quality started to gain high importance for powersupply companies and low voltage consumers since thelate 1980s. In this regard, the power distribution companies tried to improve power quality following the consumers'requests. The reasons behind the increasing attention on thisissue can be as follows: If a component fails, severe consequence will emerge due to the complex interconnection of thesystems- significant increase of harmonics in power systems -power supplier companies pay more attention to power quality due to increasing knowledge of the consumers about powerquality issues- higher sensitivity of the existing electricalequipment against the different kinds of disturbances manifested in power distribution networks[1,2,7].Today,electricalequipment producers present their products based on thepower quality level. Based on the available standards in thisregard, development of power electronic devices and the offered models to compensate for the variations in power distribution networks aim to provide the highest level of powerquality for the consumers. These power quality equipment'sare the power electronics devices which are connected together either in series or shunt and their performance is monitoredby an intelligent digital control system [3,4,9].

Permanent magnet synchronous motor (PMSM's) are finding application in air conditioning system, refrigerators, washingmachines equipment due to their high efficiency, small size and fast dynamics response[1-3]. The control schemes used forPMSM's include direct torque control (DTC) technique [3].By using this scheme electrical power conversion is performed byconverting the AC mains voltage to a DC voltage is converted into a variable frequency; variable voltage AC by means of voltagesources inverter to feeds the PMSM.

In normal cases AC-DC conversion is carried out by simply rectifying the AC input and the rectifier output is filtered by means of alarge valued capacitor to get a nearly constant DC voltage output. In this conversion the input AC supply current is drawn in narrowpulses since the capacitor voltage variation is nearly constant. This large peak narrow pulse current causes power quality problemsto nearly consumers, which includes a high values of Total harmonic distortion(THD)of supply current, high THD of input supplyvoltage ,low value of power factor (PF) and displacement factor (DPF) and poor distortion factor(DF).

In this paper, a Power Quality Improvement in Power System with PMSM Drive topology is used for providing regulated DC voltage to feed the voltage source inverter (VSI)employed in the direct torque controlled PMSM drive [4-9]. The proposed system provides improved power quality in terms of lowtotal harmonic distortion (THD), reduced crest factor (CF) of the AC supply current, high power factor of the AC mains andregulated output DC voltage.

2 Topology of Power Quality Improvement Device

The structure block diagram of the multi-objective power quality control device is shown in Figure 1. It consists of overvoltage protection device, step-down transformer, soft charging circuit, phase-shifting transformer, power unit, grounding resistance and system controller.

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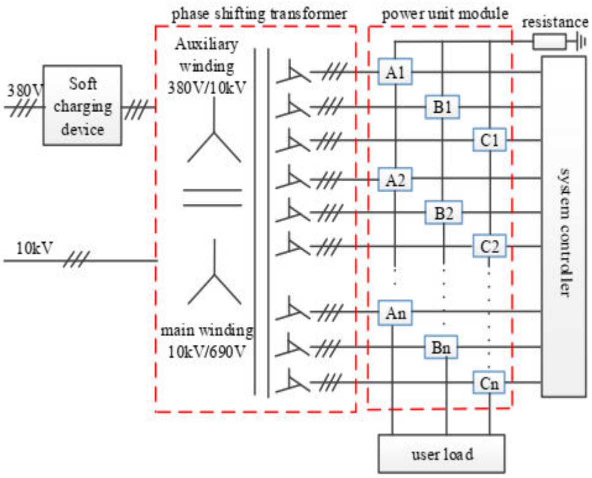

Fig.1 Structure diagram of power quality improvement device for medium voltage distribution network

In the figure, when the grid voltage is normal, the voltage of the phase-shifted transformer is converted by the power unit to a voltage that meets the requirements of load power supply. When the grid voltage is deeply diminished or interrupted for a short time, the energy is supplied by the power unit through the power unit. When the grid voltage frequency waveform, voltage amplitude fluctuation, three phase unbalance, voltage fluctuation, voltage flicker, the output voltage of the device is not affected, and it can continue to provide high-quality power supply for the load.

The power unit and soft charging loop in Figure 1 are an innovative part of the multi-objective management device and are an important part of the device, which are described in detail below.

2.1 The power unit

The power unit is composed of several modules and adopts AC-DC-AC topology structure. Each power module is composed of three-phase uncontrolled rectifier unit, single phase H-bridge inverter unit, energy storage unit and DC capacitor. The topology structure is shown in Figure 2. The power unit in Figure 2 has the following characteristics: (1) using AC-DC-AC topology, the 10kV power grid and load are effectively isolated, which greatly reduces the influence of voltage frequency fluctuation, amplitude fluctuation, three-phase unbalance, harmonics, intermittent wave, temporary Overvoltage on load and load harmonics on power quality of the power grid, and power quality is improved. (2) Energy storage unit uses the single phase conduction characteristic of power diode to realize the automatic switching of energy storage battery pack, reduces the control complexity, solves the impact of voltage sag and short-term voltage interruption on load in 10kV power grid, and effectively improves the reliability of power supply. (3) H-bridge inverters with bypass switches can effectively isolate the fault of H-bridge and its control system, and is easy to implement redundant design, which can effectively improve system reliability and reduce the impact of system failure on power supply.

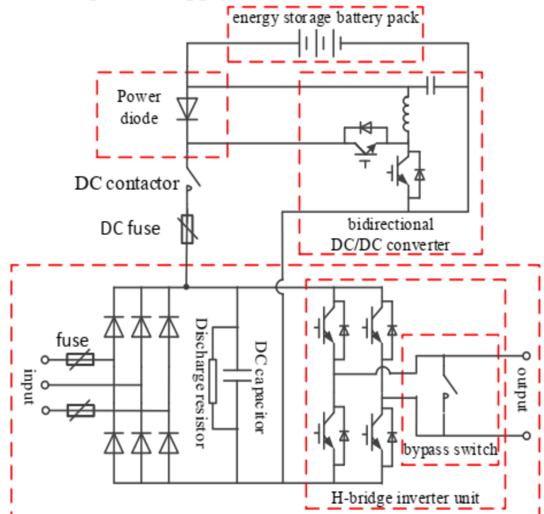

Fig2 Topology diagram of power unit model

2.2 Soft charging circuit

The soft charging circuit consists of auxiliary windings of phase-shifting transformer, multiple charging resistors and multiple contactors. Its topology is shown in Fig. 3.

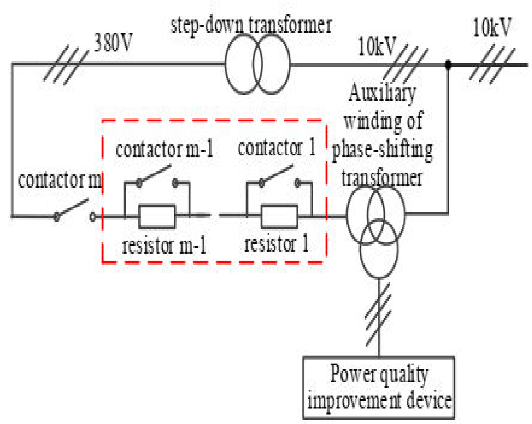

Fig.3 Topology diagram of soft charging circuit

In Figure 3, phase-shifting transformer auxiliary windings and series resistors are used to charge capacitors by phaseshifting. At the end of capacitor charging, AC contactor bypass charging resistors are closed by stages, which effectively reduce the operating overvoltage. At the same time, charging insulation of low-voltage circuit is easy to design and reduces the cost of equipment.

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3. Strategy of Power Quality Improvement Device

The control strategy of the power quality device includes output constant voltage control, energy storage module control and device abnormal state control. The overall control flow chart of the device is shown in Figure 4:

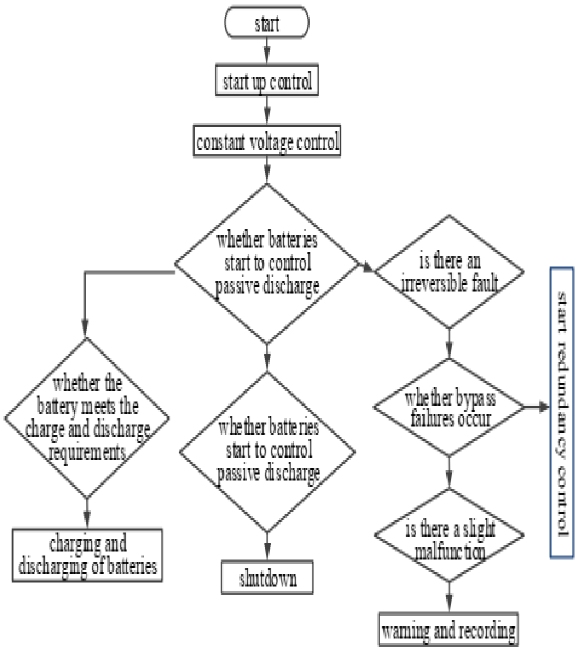

Fig.4 Flow chart of power quality improvement device for medium-voltage distribution network

At present, the double closed-loop control strategy of voltage outer loop and current inner loop is often used in constant voltage control, but the stability of the control strategy is affected by the load, and the output of the power quality device is equivalent to a voltage source, and its load With diversity, the stability of the double closed loop control of the voltage outer loop and current content is difficult.

In order to improve the adaptability of the device to multiple loads, an open-loop constant voltage control strategy is adopted. In order to overcome the shortcomings of openloop control, it is difficult to achieve zero error control, and slow closed-loop control is adopted. That is, the actual output voltage of the device is monitored, and the difference between the voltage and the control target voltage is superimposed on the command value to compensate for the voltage deviation caused by the open loop control and improve the accuracy of the output voltage.

Energy storage control can be divided into active discharge control and active discharge control according to the voltage of 10 kV side power grid. When the DC bus voltage is lower than the battery voltage due to voltage sag or short-term interruption in 10kV power grid, the diode is switched on quickly and the battery is discharged passively.

When the power grid has not experienced voltage sag or Short-term interruption for a long time, according to the operating characteristics of the battery, the battery is charged and discharged actively by the bidirectional DC/DC converter. At this time, the battery does not need to be charged according to the current at the rated capacity of the device. The battery can be charged and controlled with a small current, which can effectively reduce the cost of the DC/DC converter.

(4)Permanent Magnet Synchronous Motors (PMSMs)

Recent availability of high energy-density permanent magnet (PM) materials at competitive prices, continuing breakthroughs and reduction in cost of powerful fast digital signal processors (DSPs) and micro-controllers combined with the remarkable advances in semiconductor switches and modern control technologies have opened up new possibilitiesfor permanent magnet brushless motor drives in order to meet competitive worldwide market demands .

The popularity of PMSMs comes from their desirable features:

- High efficiency
- High torque to inertia ratio
- High torque to inertia ratio
- High torque to volume ratio
- High air gap flux density
- High power factor
- High acceleration and deceleration rates
- Lower maintenance cost
- Simplicity and ruggedness
- Compact structure
- Linear response in the effective input voltage

(a) The permanent-magnet motor technology

As with most motors, the synchronous motor (SM) has two primary parts.The non-moving is called the stator and the moving, usually inside thestator, is called the rotor. SM can be built in different structures.To enable a motor to rotate two fluxes are needed, one from the stator andthe other one from the rotor. For this process several motorconfigurations are possible.From the stator side three-phase motors are the most common. There aremainly two ways to generate a rotor flux. One uses rotor windings fedfrom the stator and the other is made of permanent magnets andgenerates a constant flux by itself.To obtain its current supply and generate the rotor flux, a motor fitted outwith

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rotor windings require brushes. The contacts are, in this case, made of rings and do not have any commutator segment; the lifetime of both the brushes and the motor may be similar. The drawbacks of this structure, maintenance needs and lower reliability, are then limited. Replacing common rotor field windings and pole structure with permanent magnets put the motor into the category of brushless motors. It is possible to build brushless permanent magnet synchronous motors (PMSM) with any even number of magnet poles. Motors have been constructed with 2 to fifty or more magnet poles. A greater number of poles usually create a greater torque for the same level of current. This is true up to a certain point where due to the space needed between magnets, the torque no longer increases. The use of magnets enables an efficient use of the radial space and replaces the rotor windings, therefore suppressing the rotor copper losses. Advanced magnet materials such as Sm2Co17 or NdFeB permit a considerable reduction in motor dimensions while maintaining a very high power density. In the case of embedded systems where the space occupied is important, a PMSM is usually preferred to an Asynchronous motor with brushes. In high-speed regions a point is reached where the supply voltage is maximum and the rotor field has to be weakened as an invert to the angular speed. In the high-speed region also called the field-weakening region, while a PMS motor needs an angle shift to demagnetize the stator windings, the SM with rotor windings maintains maximum efficiency by regulating the rotor currents and then the flux. For high-speed systemswhere high efficiency is required, AC synchronous motors with rotor windings may be a good compromise.

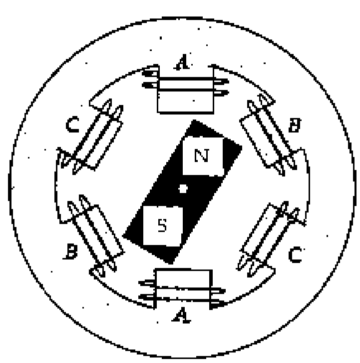

Fig 5 A three-phase synchronous motor with a one permanent magnet pair pole rotor

Two configurations of permanent magnet synchronous motor drives are usually considered, depending on the back-EMF waveform: sinusoidal type and trapezoidal type. Then different control strategies (and controlhardware) are implemented. In this document, a control for the sinusoidalPMS motor is described.

(5) SIMULATION RESULTS:

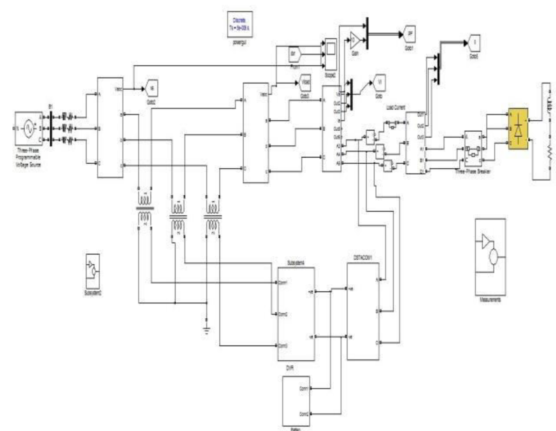

Fig 6 Simulink diagram of Proposed System

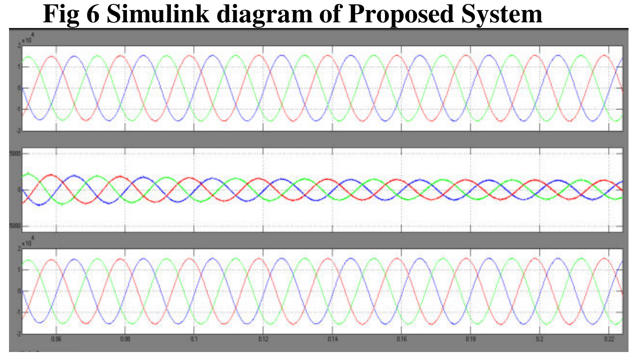

Fig.7 Simulation waveform during voltage fluctuation and voltage flicker

The simulation results in Fig.7 show that the output voltage of the device meets the requirements of the national standard when voltage fluctuation and voltage flicker occur in the power grid.

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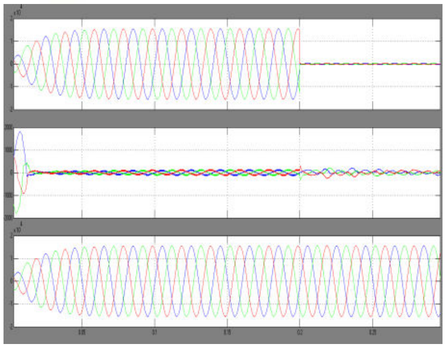
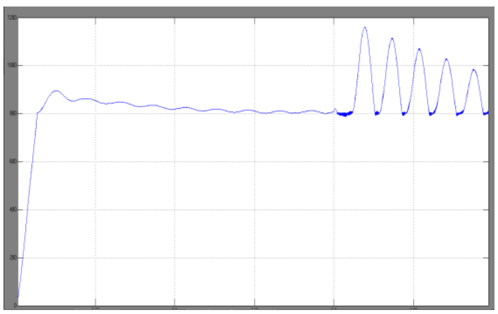


(A) voltage dip



(B) Short-term voltage interruption

Fig.8 Simulation waveform during (A) voltage dip and (B) Short-term voltage interruption

The simulation results in Fig.8 show that when the voltage of the power grid is deep sag or short-term interruption, if the DC bus capacitor voltage is lower than the voltage of the energy storage battery, the diode is switched on quickly and automatically to the battery group to supply power to the load.

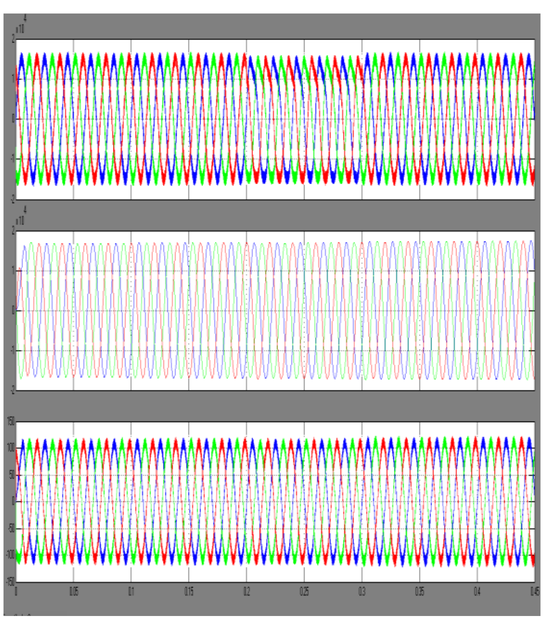
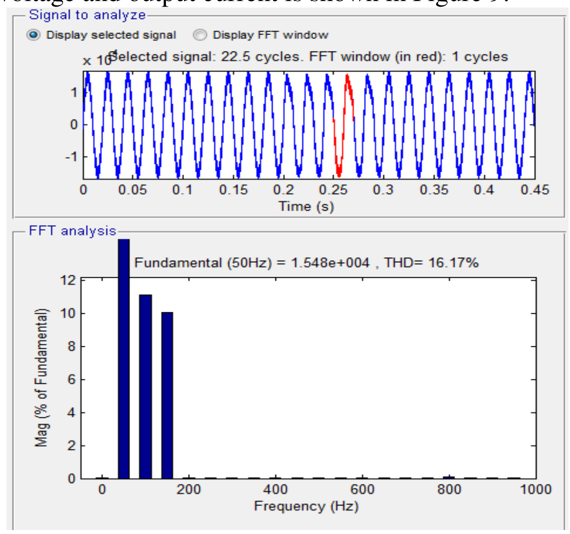
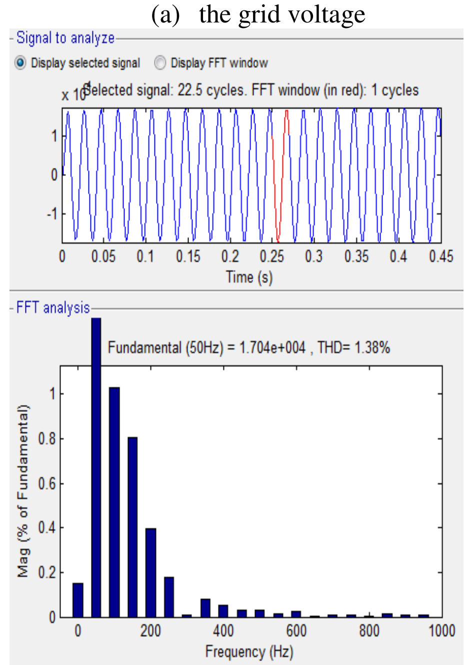


Fig.9 Simulation waveform when the grid side voltage contains harmonics

The simulation waveform grid voltage, device output voltage and output current is shown in Figure 9.



(a) the grid voltage



(b) The device output voltage

Fig.10 FFT analysis of power voltage and device voltage when the grid side voltage contains harmonics

The FFT analysis of the grid voltage and the device output voltage are shown in Figures 10 (a) and (b), respectively.

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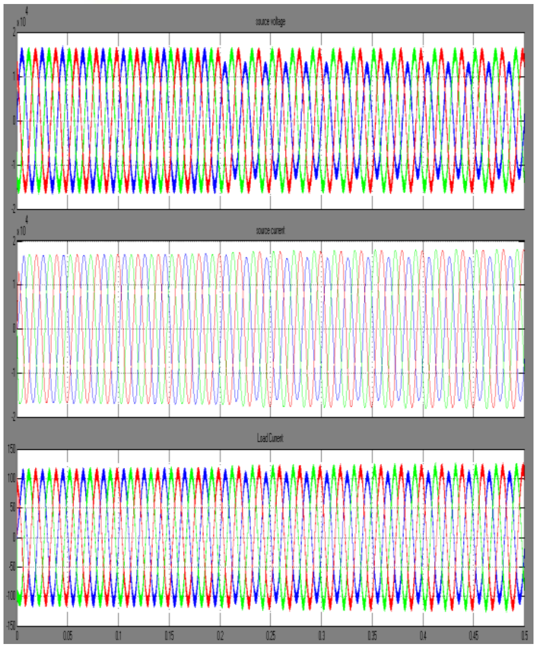
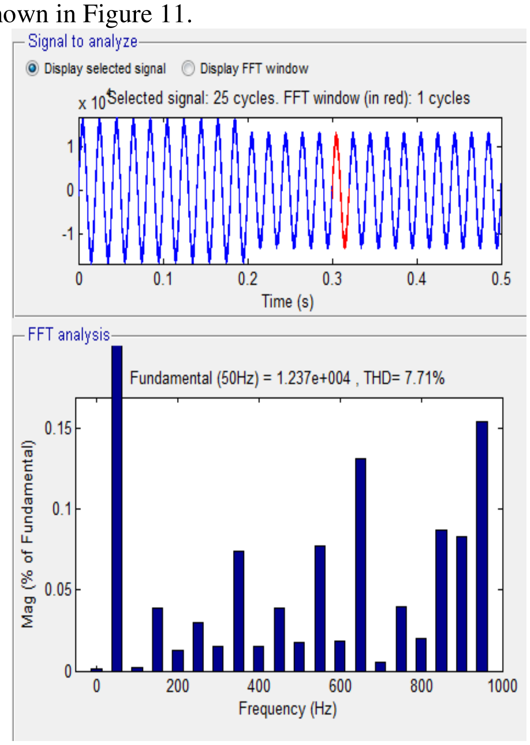
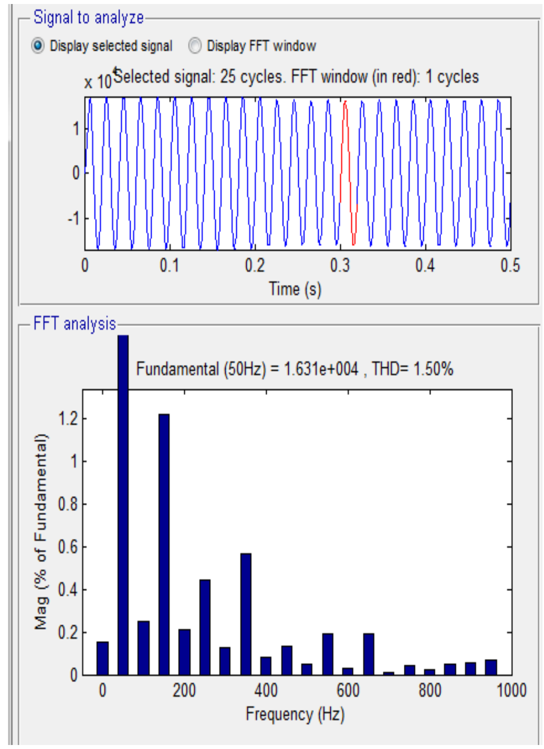


Fig.11 Simulation waveforms of frequency fluctuations, amplitude fluctuations, and three-phase unbalanced of power grid

The simulation results of grid voltage, the output voltage and current waveform of the device are shown in Figure 11.



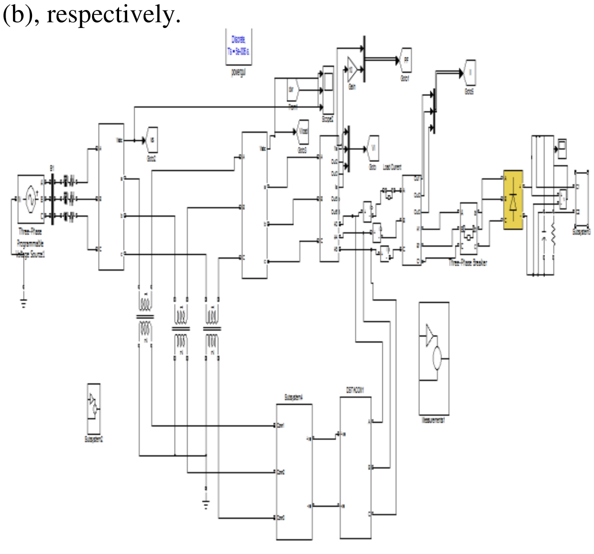
(a) the grid voltage



(b) The device output voltage

Fig.12 FFT analysis of power voltage and device voltage when frequency fluctuations, amplitude fluctuations, and three-phase

The FFT analysis results of the grid voltage and the device output voltage are shown in Figures 12 (a) and (b), respectively.



(a)

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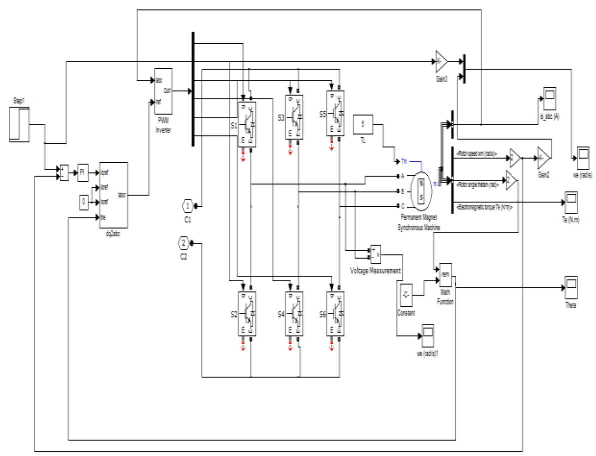
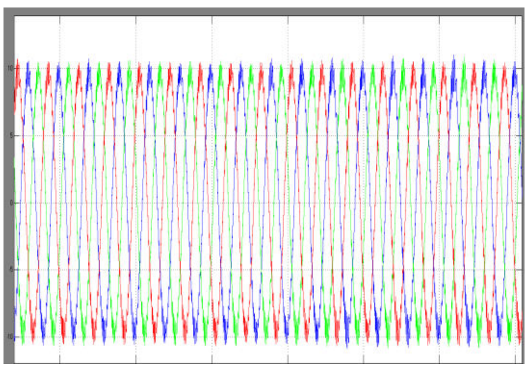
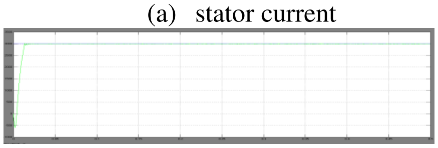


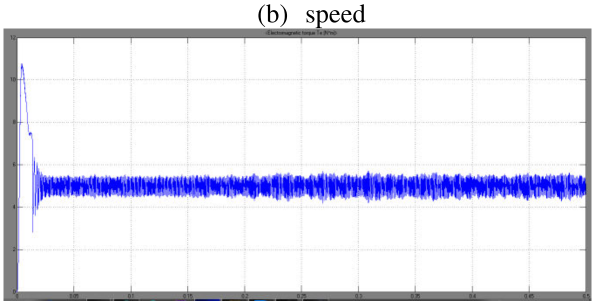
(b)
Fig 13 Simulink diagram of Proposed System with Permanent Magnet Synchronous Motor



(a) stator current



(b) speed



(c) Torque

Fig.14 Simulation waveforms of proposed system with PMSM Drive performances of stator current, speed and Torque characteristics

(6) CONCLUSION

In this project, a multi-objective comprehensive control device for power quality of medium voltage distribution network with Permanent Magnet Synchronous Motor is developed. The power unit and soft charging circuit topology of the device are designed, and a constant voltage slow closed-loop control strategy is proposed. The multi objective comprehensive treatment device for power quality of medium-voltage distribution network developed in this project can effectively solve nine power quality problems, such as frequency fluctuation, voltage fluctuation, voltage flicker, voltage sag, short-term voltage, three-phase unbalance, harmonic, intermittent wave and temporary overvoltage. It realizes multi-objective comprehensive treatment for power quality of medium-voltage distribution network and greatly improves the power supply quality of medium-voltage distribution network. And also verified the proposed system with PMSM Drive performances of stator current, speed and Torque characteristics.

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