ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Energy Procedia 17 (2012) 813 – 817
Energy Procedia

2012 International Conference on Future Electrical Power and Energy Systems

# Improving Power Quality by Smart Load

LI Bao-shu[1], GE Yu-min[2]

*[1]School of Electrical Engineering*
*North China Electric Power University*
*Bao Ding, China*
*[2]School of Electrical Engineering*
*North China Electric Power University*
*Bao Ding, China*

**Abstract**

This article analyzes the influence to the power quality produced by load, pointing out that common load can become smart load to improve power quality with the application of computer technology, digitized technology and information technology. Meanwhile, function and status of smart load to the power network are emphersized. Also in view of each target of power quality, some examples of improving power quality by smart load (shown as Figure 1 and Figure 2)are given.



*Keywords- smart grid;smart load; power quality*

## 1. Synopsis of smart load

Smart grid[1-5] construction concludes four links as electric generation, transmission, distribution and using. Smart loads belong to the last link and play important roles. The development of smart loads not only meet the need of smart grid, but also manifeste the progress of power system and society.

Smart load is not a new concept. For example, smart electrical appliances belong to smart loads. With the application of computer technology, digitized technology and information technology, typical electrical appliances can become into smart ones with the function of intellectualization and informationization[6].Electrical equipments, especially large and important ones will be smart loads with the application of those above technologies.

Smart loads have follow characteristics comparison to common ones:

- Remote control.Control the automatic switching by network.

 doi:10.1016/j.egypro.2012.02.174

- Running state examination. The running state can be examined automaticly and fed back to related department by network, so the department can know the status of loads momentarily.
- Power quality examination. Voltage sag, three-phase voltage imbalance, etc. can be examined. When the power quality can't meet the need of loads,the information is uploaded and the power is cut to guarantee the safe of loads.

## 2. Influence to power quality by loads

Power quality is a question that valued by both power supply department and user. At one aspect, the safe, steady running of power network is influenced for the loads become more complex and diversified. At another, loads which is sensitive require perfect power quality. With the development of technology and national economy, the standard of power quality will be more strict.

There are mainly three aspects that effect power quality. One is internal fault of power supply department. Another is external disturbance. Final is load. So load is one of the main factors that affect power quality[7].

Change of power quality made by load can be summed up as follow.

- Load position;
- Load starting;
- Nonlinearity load;
- Shocking load.

As common load, those above situation can't be changed real-time easily. Smart load can do it.With the help of computer technology, digitized technology and information technology, smart load can change load position and way of starting, make nonlinearity load linearization, reduce the attack of shocking load to improve power quality.

## 3. Improving power quality by smart load

### *3.1 Harmonic Suppression*

Harmonic is caused mainly by nonlinearity load. To suppress harmonic with cost-effective method has great meaning to make power quality better and guarantee safe-running of electric equipment.

Switch time for common load is stochasticly. While for smart ones it's controllable. Surely there is a best switch time for load to make the line-current optimalizing, even better than before. When the load hadn't switched. Harmonic can be suppressed without increasing any equipment if load is switched at the best time. Then the power quality is improved and the load bocomes a smart one. A multi-harmonic-source model is shown as Figure 1. The invertor is connected at 0.002S and 0.008S,controlled by a switch. The data of total harmonic distortion(THD) of C-phase current and main harmonic rate are shown as TABLE Ⅰ and TABLE Ⅱ.

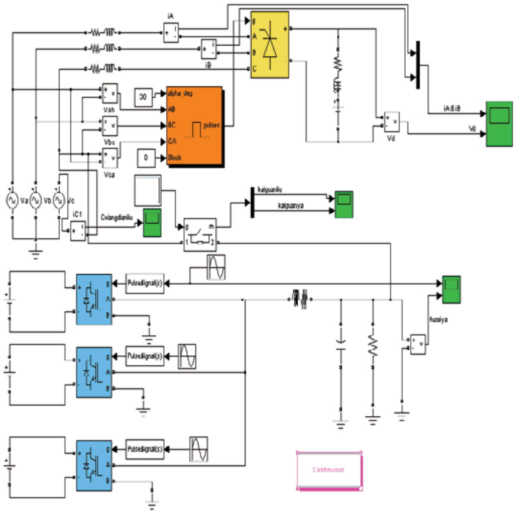

Figure 1. Multi-harmonic-source Model

TABLE Ⅰ. THD of c-phase current and main harmonic rate at 0.002s

| **THD** | **2nd Harmonic** | **3rd Harmonic** | **4th Harmonic** | **5th Harmonic** | **7th Harmonic** | **11th Harmonic** |
|---|---|---|---|---|---|---|
| 1.50% | 1.18% | 0.56% | 0.39% | 0.25% | 0.15% | 0.11% |

TABLE Ⅱ. THD of C-phase Current and Main Harmonic Rate at 0.008S

| **THD** | **2nd Harmonic** | **3rd Harmonic** | **4th Harmonic** | **5th Harmonic** | **7th Harmonic** | **11th Harmonic** |
|---|---|---|---|---|---|---|
| 1.70% | 1.41% | 0.58% | 0.40% | 0.25% | 0.20% | 0.14% |

It is obvious that the current quality is different if the invertor is connected to network at different time[8].

The conclusion is the same when load is cut away from the network. How to get the best time? First, survey and calculate the THD of the line-current. Then simulate the situation that the load is connected or cut away from the network. The best switch time can be determined by analysising the simulation data..

### *3.2 Avoiding Voltage Sags*

Equipments like computer, variable frequency speed regulation motor, programmable logical controlle (PLC),etc. will not work normally with voltage sags. There are two reasons that can cause voltage sags. One is short circuit fault happened in the system, the other is starting induction motor. A model of starting induction motor is shown as Figure 2. After starting the motor, stator current increases and the current of system impedance ($Z_s$) increases too. Then the voltage of $Z_s$ increases and the voltage of PCC drops.

voltage sags occur. If currents of other loads are small, the influence of voltage sags will be obvios. Otherwise, the influence will be small even none[9].The motor can judge whether serious voltage sags will happen after connecting one load by simulating the situation if the motor is a smart load. If the consequence is serious, measures like shunting capacitor, step-down and so on will be taken to avoid voltage sags.

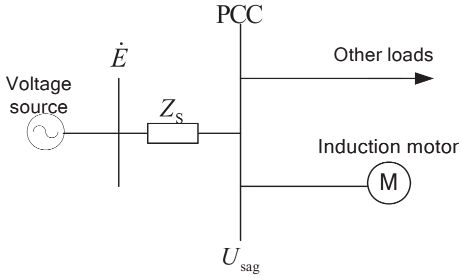


Figure 2. system model of starting induction motor

### *3.3 Avoiding Voltage Flicker*

Voltage flicker will make the motor rotate speed non-uniform, electronic installation abnormal, electrical energy measure inaccurate and so on. There are three aspects that can cause voltage flicker. First is because of power source. Second is motor starting frequentiy. Third is shock load connecting to network. So voltage flicker is related with load. The consequence caused by the last one is most serious. Common shock loads are arc-furnace, mill, electric locomotive, etc[7].

When motors or shock loads are connected to network, line-voltages, currents and frequency are measured by measuring unit. Then the value of possible short-time voltage flicker( $P_{st}$ )is calculated. If $P_{st}$ is abnormal, corresponding methods like connecting the load to fitable line or starting compensation device at the same time are taken.

### *3.4 Reducing Three-phase Unbalance*

Three-phase unbalance will cause a series of harm like adding additional loss of transformer, protection malfunction, adding loss on midline and enlarging obstruction to communication system. The main factors that cause three-phase unbalance are classified into two sections: faulty and normality. The former is because one or two phases are faulty, the latter is because three-loads are unbalance[3].For example, one-phase load unbalance can cause three-phase unbalance. If the load is a smart one ,its measuring unit can survey the magnitude of every phase, then the executive element connects the load to the phase whose load is the smallest. By this way, For online loads, three-phase unbalance can be reduced by deallocateing them to each phase..

### *3.5 Reducing Frequency Deviation*

As is known to all, rotate speed of generating set can keep invariable only when system power requirements match the power source supply. But both of them change momentarily. Frequency deviation will appear when the two are out-of-balance. This will harm both the power-supply side and the power-demand side. For example, it can reduce efficiency of generating set, increase reactive power, change rotate speed, influence the accuracy of power-measurment equipment and so on[10].

The most typical example that makes frequency deviation better by load is low frequency load shedding. When the frequency is too low to run normally, many smart loads will give alarm and application for exit. But all these loads quit running is impossible. Surveillance center will execute synthesis analysis and prioritization according to the character and the nature of loads and the structure of line to assure which load quits running. By this way, both frequency deviation can be standardized and losses of users can keep least.

*3.6 Reducing Overvoltage*

Only those overvoltages that appear because of load shedding are discussed in this article. When a set of loads need to be shed, the voltage, active power, reactive power of the line are measured first. Then the consequences of load shedding are simulinked. The loads can be shed batchwisly or one by one if the consequence is serious. The shedding order can be optimized too. If a large load shedding causes overvoltage, a small one can be connected to the line coinstantaneously to reduce the influence of load shedding.

## 4. Conclusion

To meet the need of smart grid construction in our country, this article clears the importance of smart loads, points out the power quality questions caused by loads and explains that power quality can be improved by smart loads. Also in view of each target of power quality, some examples of improving power quality by smart load are given. These examples are hopeful to apply in smart grid.

## References

[1]JING Enbo.Overview of Development and Technology of Smart Grid.Low Voltage Apparatus, 2010,6:14-15.

[2]YU Yi-xin ,LUAN Wen-peng.Smart Grid. Power System and Clean Energy, 2009,25(1):7-11.

[3]EPRA.Profiling and Mapping of Intelligent Grid R&D Programs [R].EPRI,Palo Alto,CA and EDF R&D,Clamart(France) ,2006.

[4]Paul Haase.IntelliGrid:A Smart Network of Power[J].EPRI Journal, 2005:17-25.

[5]European Commission.European Technology Platform Smart Grids:Vision and Strategy for Europe’s Electricity Networks of the Future[EB/OL].http//ec.europa.eu/researeh/energy/pdf/smartgrids_en.Pdf. 2006.

[6]SUN Mei-mei.Current and Future Situation of Smart Electrical Appliances. Technetronic Technology, 2006,9:10-12.

[7]CHENG Hao-zhong.Power Quality[M].Beijing: Tsinghua University Press,2006.

[8]GE Yu-min,LI Bao-shu,LIANG Shuang. Research of Mitigating Harmonic by Harmonic in Multi-harmonic Source System. Electrical Engineering, 2008,9:119-121.

[9]XING Ying. The impact of the Electric Loads on Voltage and Current of the Grid[D].North China Electric Power University,2007.

[10]XIAO Xiang-ning.Analysis and Control of Power Quality [M].Beijing:China Electric Press,2004.