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Investigation Into the Effects of Non-Linear Loading of Domestic Power Network on Home Appliances

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Non-Linear loads such as Compact Fluorescent lamps (CFLs), Light Emitting diodes (LEDs),Solid state voltage regulators, and variable speed electric drives are increasingly being added tothe domestic, residential and industrial power network. These light sources and other house-hold appliances using power electronic converters are termed as non-linear loads and they introduce distortion in the power network by generating harmonics in the current, leading to poor power quality [1–4]. Power quality issues are now becoming a major concern because of several reasons: a) Increasing dependence on electrical supply and even small disruption or interruption are not bearable because it can halt the modern lifestyle, b) new modern electrical equipment are highly sensitive to the power quality and c) the power electronic components such as variable speed drives and switched mode power supplies poses new disturbance challenges to the electrical supply network [5–7]. Power quality standards such as IEEE 519 is proposed to: a)assure that the electric supply company should deliver clean electric power to the consumers, b) assure that the electric supply company can protect electrical equipment from excessive voltage stress, overheating and loss of operational life of equipment. The IEEE 591 standard is in place that puts a limit on the allowed harmonic distortion of 3% on individual harmonic components and 5% on total harmonic distortion (THD). This standard is of utmost importance on the present day situation due to increasing non-linear loading. Although the distortion limits are not applied to specific equipment, however, with a high penetration of non-linear loads, it is likely that some harmonic suppression may be necessary [8–12]. The power quality problem is a distortion in the voltage waveform of the power source which is deviation from sine wave. Another power quality problem is a change in the amplitude from an established reference level. Other disturbance can be caused by harmonics in the current. With increasing the number of harmonics generating devices in a power system network, the problem of their impact on the performance of system components like induction motors needs is becoming a serious problem that need further consideration. It is well known that approximately 60–70% of loads in all over the world are motor loads. Most of

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the motors used in the world are three-phase induction motors. However, single-phase induction motors are major load in a domestic or residential setup. The modern day home uses large number of house hold appliances that uses different kind of single-phase motors as given in Table 1. A power network is shown for a domestic house in Fig. 1. Mix of loads are connected across the line. The effects of increasing non-linear loads in residential setting can be significant especially on single-phase motors connected to the same line. This paper investigate the effect of increasing distortion in the supplied voltage on the performance of single-phase induction motor behavior. Firstly the effect of increasing distortion in the applied voltage waveform on stator current is investigated. It is found that increasing a small %age of 3rd harmonic in the applied stator voltage significantly increases the 3rd harmonic component in the stator current. When voltage is pure sine wave, the current contains 1.7% 3rd harmonic. When the stator voltage is injected with 2.5% of 3rd harmonic the resulting current contain 11% 3rd harmonic. Hence it is concluded that current harmonic content is strongly dependent on the harmonic content in the stator voltage waveform. A Matlab/Simulink model is developed with single-phase capacitor start machine. The procedure adopted is as follows:

- Pure sine wave is applied to a capacitor start single-phase induction motor.
- Distorted supply is produced from inverter using appropriate PWM scheme and supplied to a capacitor start single-phase induction motor Non-linear loads such as CFLs and LEDs are emulated using thyristor based converter.

The thyristors are switched at different firing angle in order to vary the harmonic content in the supply voltage. The behavior of single-phase induction motor under distorted voltage conditionis recorded. The setup shown in Fig. 2 is consist of a single phase capacitor start induction motor supplied with PWM Converter. The motor is rated for 110V rms, 1500 rpm and 0.5 HP. The reference of the converter is generated by adding 3rd and 5th harmonic component to the fundamental component. The loads are switched in this order: Fig. 2. Single-phase induction machine (capacitor start) setup. a) At t=0, the controlled rectifier with thyristor switching at 30° is turned on. This rectifier will always be on. The current drawn from the supply is analyzed for harmonic components. Each harmonic component contribution becomes input for reference generation for PWM Inverter. b) At t=2 Sec, the controlled rectifier with thyristor switching at 60° is turned on. Now we have two controlled rectifier connected to the same ac supply. The resultant current is analyzed for harmonic component contribution. c) At t=4 Sec, the controlled rectifier with thyristor switching at 90° is turned on. d) At t=6 Sec, the controlled rectifier with thyristor switching at 120° is turned on. Efficiency estimation, a) The output of the system is calculated by multiplying load torque with the motor speed (in rad/sec). b) The input of the system is calculated by extracting P, Q, S from the bridge output voltage and current drawn by the motor from the block as shown below in Fig. 3. Efficiency computation of a single-phase capacitor start machine. c) Fundamental frequency, 3rd harmonic and 5th harmonic power is estimated by using the above block. The resultant power is calculated as: d) With the resultant absolute power drawn from the system, efficiency is calculated as: The simulation results are presented in Fig. 4–6. Ripple is seen in the current, torque and speed when voltage is distorted. The FFT of stator current (main winding) is shown in Fig. 7. Strong 3rd harmonic current is seen and also 5th harmonics.Sinusoidal Supply: Fig. 4. Single-phase IM behavior when pure sine wave is applied. Supply from a single-phase Inverter with Fundamental frequency (50 Hz) only: Fig. 5. Single-phase IM behavior when supplied from a DC/AC inverter. Supply from a single-phase Inverter with Fundamental, third and fifth harmonic: Fig. 6. Single-phase IM behavior when supplied from a DC/AC inverter with distorted waveform Fig. 7. Harmonic spectrum of stator current under distorted voltage source. Different powers are measured and shown in Fig. 8 for pure sine-wave supply and distorted voltage supply to a single-phase capacitor start induction machine. It is observed that the requirement of active, reactive and apparent power increases and efficiency decreases with the increase in the voltage distortion.

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