Automatic detection and identification of electric loads at the event of switching-on that load

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***Abstract*-Automatic detection of the event of switching-on an electric load, estimation of that switch-on instant and subsequent automatic identification of that electric load using current transient signal around the switch-on instant are studied in this paper. The time variation of the current harmonics is used to first detect the event of switching-on an electric load and then spectral features extracted from the current harmonic signal around the estimated switching-on instant is used for automatic identification of that load. In particular, feature based on the second derivative of the magnitude of second harmonic of the current signal is proposed to be used for automatic detection of the event of switch-on. This feature provided an error rate of 9.4% of event detection with 0.27 seconds of average error in estimating the switch-on instant. Finally, the overall system that combines this detection of the event of switch-on and the automatic identification of that load gave an accuracy of 87.5% in a cross fold validation experiment tested with four loads.**

Index Terms— Electric load identification, transient current, Short Time Fourier Transform, nonintrusive load monitoring.

I. INTRODUCTION

The automatic detection and identification of electric loads is important in several applications such as high efficiency buildings to control the energy consumption [1], and to effectively manage loads in self-configuring microgrids [2]. For example, in the case of an overload condition in microgrids, an automated demand side management system can selectively switch-off loads if it can automatically identify loads. A proper load identification system can help increase system efficiency by reducing the energy consumption and thus minimising carbon emission [3]. Identifying loads by installing sensors in each load is an expensive and intrusive way of load identification, while identification using electric parameters that can be estimated at the power meter outlet is a non-intrusive and inexpensive method [1]. This non-intrusive method of identification can use current, voltage, active or reactive power, current harmonics and phase angle. A detailed review of methods of load identification can be found in [3, 4]. Though several methods are available, this problem of load monitoring is classified as a subject of high difficulty and requires even more investigation [4].

Loads can be identified using their steady-state waveforms [5] or transient waveforms [6]. Most of the research already reported are based on steady-state waveform. For transient based load identification at the feature extraction stage, the spectral envelope of a current waveform is used in [6] and instantaneous power of a switching transient waveform is used in [7, 8]. Though challenging, methods based on transient waveforms aim to identify those loads as soon as they are switched on and this is very useful for an effective load management. For example, in home or in a commercial building this automatic load management system can introduce a low power mode by selectively switching-off unnecessary loads whenever it detects an appliance such as electric heater or water pump to maintain the overall power consumption.

Generally automatic load identification based on the transient waveforms at the time of switching-on involves two stages: (i) automatic detection of the event of switch-on together with the estimation of that switch-on instant, (ii) automatic identification of that load. Previously the work reported in [9] dealt with the problem of automatically identifying the load using their transient, in particular when switching-on, waveforms using hidden Markov models (HMM) as a classifier for non-intrusive load monitoring (NILM) systems, using manually recorded switching-on instants. This paper extends that work by automatically detecting switching instant and then automatically identifying the load without using manually recorded switching-on instants. Specifically, in this work an automatic event detector, based on the second derivative of the short-time magnitude of the second harmonic of current signal, to detect switch-on event and to estimate the switch-on instant is proposed.

The transient based load identification system reported in [6] used an analogue preprocessor for the event detection, and for the load identification a least square based approach is used. The work reported in this paper does not use any analogue preprocessors and for the automatic load identification HMM based classifier is employed.

The reason HMM is best suited for this kind of application is described below. It was stated in [10] that the transient behaviour of a typical electrical load is strongly influenced by the physical task that the load performs. That is, when the load changes from off-state to on-state due to the gradual change in the electric characteristics of that load when electrons start to pass through, the current waveform may change to several unknown numbers of intermediate states before it comes to a steady state. It is very difficult to isolate

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