Electrical Power Supply Management in Normal and Supply Deficit Situations for Residential Consumers Based on Appliances Priority Consideration, Fairness Evaluation, and Activity Identification

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論 文 名　: Electrical Power Supply Management in Normal and Supply Deficit Situations for Residential Consumers Based on Appliances Priority Consideration, Fairness Evaluation, and Activity Identification
（需要家の優先度配慮と公平性評価および行動推定に基づく通常時および供給不足時の住宅需要家向け電力供給管理に関する研究）

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論 文 内 容 の 要 旨

The balance between the electric power supply and demand is crucial in power system operations. Power Plant Operators (PPOs), Transmission System Operators (TSOs), and Distribution Utilities (DUs) are working hand in hand to maintain this balance. Over the years, a rapid increase in power demand brought by technological advancement makes the balance between supply and demand very challenging. In the majority of the developing nations, the electric power supply capacity is not increasing at the same rate due to some limitations such as extensive government processes and environmental regulations in putting up new power generating plants, the variability of renewable energies, depletion of non-renewable sources, and huge investments, among others. In this case, disruptions in power system operations due to this imbalance are inevitable. In supply deficit power systems where the consumers' power demand largely exceeds the available power supply, DUs are obliged to perform load shedding (LS) in order to maintain the system voltage and frequency levels as stated in the manual in power operations for conveying electricity to its consumers. Currently, most DUs implement feeder-level LS but several studies show that feeder-level deloading incurred unnecessary LS, and a large portion of the consumers are affected in such times. On the other hand, in the normal day-to-day operation of a power system, DUs carefully determine the consumers' daily load profiles to ensure that their purchased or contracted energy is sufficient to meet the consumers' demand. It is also equivalently important to check the level of energy utilization, relative to the available power supply because inefficiency in energy usage leads to profit reduction for the DUs (i.e., when the contracted energy is higher than the actual power consumed by the consumers) and a higher power rate charge to consumers (i.e., when the contracted energy is less than the actual demand). The most challenging to determine is the residential consumers' load profile due to wide variations of activity and schedules performed individually. A reliable day-ahead forecast of residential consumers' power consumption greatly improves the overall system load profile which is crucial in the DUs' daily operations. Thus, it is efficient and logical to analyze the individual consumer's demand rather than the usual aggregated consumer load forecasting strategy. This strongly motivates a new modelling/forecasting technique of the load profile of residential consumers. To solve these issues, this thesis proposes two methods that will aid in the efficient management of electric power supply during normal day-to-day and emergency operations considering residential consumers' activity and their respective preferences. One is an appliance-level LS strategy that is developed to efficiently allocate the available power supply for every residential consumer during power deficit situations applicable in real-time operation. This method enables every consumer to decide which appliances to voluntarily de-load. Also, it gives consumers the chance to choose their preferred appliances to have a high probability of being energized and opt not to experience a total power outage even an LS implementation is necessary. Moreover, a margin of error is being considered in the utilized short-term load forecasting strategy to accommodate the errors incurred in any forecasting strategy employed. Furthermore, the effectiveness and viability of the introduced method are illustrated to further strengthen the research claim. The result shows that closer evaluation and improvements in the proposed method confirm the promising outcomes with significant accuracy. Also, the proposed method is a sound investment since the un-utilized energy could be an additional revenue for the distribution utility. Furthermore, consumers satisfaction will be elevated since they can take part in deciding which appliances to turn off first during load shedding implementation. In effect, distribution utilities will have a fair, automated, and efficient load shedding process which improves system stability, reliability and power quality. Another method is a load forecasting strategy that determines individual residential household appliances' usage as routine and non-routine activities. Routine activity is determined as the appliance usage that appears frequently, otherwise, it is a non-routine activity. An algorithm is developed to reconstruct the daily load profile by initially assigning a time interval to the determined routine activity and its corresponding power consumption. Moreover, due to a probabilistic nature in determining the routine activity and its power consumption, a cumulative density analysis is performed to provide the most probable power consumption value in a certain time-interval. The result shows a considerably good enough solution to represent the actual daily power consumption of an individual household, which signifies the proposed method's accuracy. Hence, the proposed method is very promising in representing the actual residential power consumption. This suggests a lot of advantages such as sustaining power reliability, reduce waste energy, avoid penalties and excessive power rates, and satisfied consumers, among others.

The thesis is presented as follows:

Chapter 1**:** the motivation of the study is described and the research objectives are presented in order to establish the research goal and concept.

Chapter 2**:** related studies are presented to provide a basis and understand the need of the present study. Also, recent reports and research advancements are shown to emphasize the novelty and the much-needed technology to ensure power supply-demand stability.

Chapter 3**:** the network topology is described to provide a thorough understanding of the research system design and architecture. Here, the centralized and distributed optimization strategy are combined to ensure the real-time applicability of the proposed method.

Chapter 4**:** the proposed method for LS implementation during emergency situations is introduced. Moreover, A short-term load forecasting and the combined centralized and distributed optimization strategy using Genetic Algorithm are proposed in an appliance-level LS implementation.

Chapter 5**:** a method improvement, performance evaluation, and a viability analysis of the previously proposed method for LS implementation during emergency situations are discussed.

Chapter 6**:** a reconstruction of consumers' daily load profile considering consumers' daily activity is introduced to aid DUs energy procurement decision making in a normal day-to-day situation.

Chapter 7**:** conclusions are drawn to summarize the study's significant outcomes. Furthermore, future plans have been provided for possible improvement and future direction of the research.