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Evolutionary algorithm based optimum scheduling of processing units in rice industry to reduce peak demand

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ABSTRACT

In India, power shortage is a major issue for economical growth. According to the data provided by National Load Despatch Centre, peak power shortage in Tamilnadu during the year 2014 varies between 3000 MW and 4000 MW. This power shortage can be reduced by increasing installed capacity of conventional and non-conventional energy sources. But the construction of new generation plants is cost-effective and also power generation is not assured throughout the year. This power shortage can also be minimized by implementing load management in the consumer side. This paper focuses on the reduction of peak demand by the proper operating schedule of major equipments. For this analysis, three rice industries have been considered. The major operating sections in the rice industries are pre-cleaning, soaking, pre-milling and milling. In this proposed work, to reduce the peak demand, the operating time of pre-milling section is rescheduled using the optimization techniques, DE (Differential Evolution), PSO (Particle Swarm Optimization) and ABC (Artificial Bee Colony). The rescheduled results given by DE, PSO and ABC algorithms reduce the peak demand cost of the energy consumed in three rice industries. However, the optimum scheduling obtained by ABC reduces the feeder power flow than the DE and PSO scheduling.

1. Introduction

EEM (Electrical Energy management) activities will reduce the cost of electricity in industries. In India, the industrial sector consumes major electrical energy. Numerous analytical studies have been undertaken on energy conservation for different industries, such as the paper and pulp industry [1], cement industry [2] and ROM (run-of-mine) ore milling circuit processing platinum bearing ore industry [3], power generation industry [4], glass industry [5], and steel industry [6]. The energy conservation activities carried out in a Taiwanese paper and pulp industry have identified that the maximum energy-saving potential is depends on improving the energy equipment efficiency and distribution [7]. Analysis on certain energy conservation policies indicates that the elasticities of energy price, industrial structure, the profit margin has significant impact, as they are negatively correlated with changes in energy intensity. The conclusion of the energy audit in the Malaysian rubber producing industries has shown that the major fraction of total energy is consumed by electric motor, pumps, heaters, cooling systems and lighting. The use of high efficient motors and VSD (Variable Speed Drive) has been proposed to reduce energy consumption of motors that are used in rubber industries [8].

Rice is a most important food crop for world's major population. India accounts for 20% of the world's total rice output. Rice milling is the oldest and the largest agro processing industry of the country and is one among the most energy consuming industries. By the year 2012, it had a turnover of more than 36,500/- crores per annum. Every year, India processes about 85 million tonnes of paddy to provides staple food grain and other valuable products required by the population [9]. There are two types of mills engaged in rice processing i.e. conventional and modern rice mills. Conventional rice milling is an inefficient and an age old technology in which, the paddy processing is carried out by using steel hullers. Modern rice mills use a modern technology, which is more efficient. In these modern rice mills, paddy processing is carried out by using rubber roll shellers. Now-a-days, more than 70% of the overall rice production of the country is processed by modern mills, and

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Nomenclature

An	number of pre milling units in an industry
c_1	constant used in PSO
c_2	constant used in PSO
C_i	power consumption of other loads like compressor, pre-cleaning, milling, soaking and lighting load in kW
dV_i^{k+1}	change in velocity
dom_i	number of solutions in the current population
f_1	fitness 1
f_2	fitness 2
$Gbest$	global best in PSO
j_{sh}	shut down period
m	number of loads
n_j	number of pre-milling units to be operated at the jth period
Np	number of particles
NS	number of food positions
P	power rating of one pre-milling unit
$Pbest$	particle best
P_r	total number of pre milling units to be operated in a day to complete the process
$rand_1$	random number 1
$rand_2$	random number 2
V_i^{k+1}	velocity of ith particle during k+1th iteration
v_{ij}	new value of employed bee position
ω	inertial weight
X_i^k	position of ith particle in kth iteration
ρ_i	random number between 0 and 1
$\varnothing_{ij}$	random number between 0 and 1

remaining 30% by means of conventional mills. In these industries, the major energy consuming equipments are boilers, blowers, pumps, belt conveyors, elevators, motors, etc. [10]. The countries harvesting surplus amount of rice can produce heat and electricity from rice-straw and hush to meet the energy requirement [11]. Thus, energy management in these industries is essential today. The main reason is that these energy management activities provide remedial measures during the energy crisis by tremendously reducing the gap between generation and demand. The energy conservation activities in the rice industry lead to the reduction in the use of fuels and electricity that would simultaneously reduce the cost of milled rice.

Electricity shortages are aggravated by inefficiencies mainly in end-use system. This is mainly due to irrational tariffs, technological obsolescence of industrial processes and equipments, lack of awareness, and inadequate policy drivers. The only way to handle these crises is to overcome these inefficiencies in the end users system and it can be achieved with DSM (Demand Side Management) strategy. TOU (Time-of-Use) tariff is often used by utilities to encourage the implementation of load shifting techniques. Some utilities also apply MD (Maximum Demand) tariff, which is an additional fee that must be paid, based on the basis of maximum power consumption. Today, DSM (Demand Side Management) is driven by the utility or the state in the form of direct command or incentives, into a customer driven and the customer finance stage. Hence, the ultimate aim of DSM has become demand cost savings.

The per capita energy consumption has been continuously increasing, especially in the developing countries like India. Electrical energy consumption growth in these developing countries has been increased due to major developments in commercial, industrial and transport sectors. Due to rapid industrialization and growing urbanization, there arises a need for large amount of electrical energy demand which cannot be met by present day generation capacity. By the year 2030, the global energy demand is forecasted to increase by 43–45% of the current total of 472 quadrillion Btu to 678 quadrillion Btu. To bridge this huge gap between generation and demand, constructions of new generation plants are required, which is a costly affair and also causes climatic changes due to greenhouse gas emissions. Therefore, an urgent need to focus on energy management activities arise which is cost effective and also reduces environmental pollution. Energy management is one of great importance in view of the fact that one unit of energy saved at the consumption level reduces the need for generating capacity by 2–3 times. Paulus and Borggrefe analyzed the energy consumption of different industries in Germany [12] and this provides essential information of energy consumption pattern in each process. It helps to identify the areas of demand saving opportunities. Mirlatifi et al. presented a model to estimate the annual peak demand of electricity based on historical annual databases, analysis of variance, and the statistical methods by considering a number of customers, price of electricity, the number of tourists and population. The performance of the proposed model was measured using mean absolute scaled error and mean absolute percentage error for in-sample and out-of-sample data [13]. Mohammad Rozali et al. analyzed variation in electrical load distribution due to the time of operation of equipment and process and weather condition. They proposed the power pinch analysis to reduce the electricity maximum demand and to optimize the overall electricity cost by performing cost-effective load shifting. The electricity cost has been reduced by shifting on peak electrical load to off peak duration [14].

The increasing demand for electricity leads to considerable fossil fuel burning, which in turn has an adverse impact on environmental activities. It has been estimated that nearly 20,000–25,000 MW of electricity can be saved by implementing end-use energy efficiency measures and demand side management strategies throughout India. EEM is one of the activities which reduces the peak load demand and reshapes the load curve without affecting the production. The peak load demand shortage conditions in the year 2010–11 was 9.8 percentage and it increased to 10.6 percentage in the year 2012–13 [15]. Various studies on load shifting techniques illustrate that reduction of peak demand will avoid new generation capacity addition and will help utility to achieve a significant peak-demand reduction by minimizing their operational cost. A real time load shifting control of residential energy management has resulted in demand cost savings [16]. This load shifting is done in response to the electricity tariff structure implemented by utilities. The commonly used electricity rate structure includes TOU (Time of Use), CPP (Critical Peak Pricing), PTR (Peak Time Rebate) and DP (Dynamic Pricing). The most commonly used tariff structure, TOU charges both for energy consumption and peak demand. It refers to the electricity rate structure in which customers pay different prices at different times of a day. Reduced peak demand will result in less stress on power generation facilities during peak periods and helps to maintain stable reserve margin. The TOU rates used with the load shifting method may also encourage new loads to occur during the off-peak partial peak periods. Turner et al. used an advanced airflow, energy