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Aims and Scope

Journal of Industrial and Mechanical Engineering is a peer-reviewed journal for the presentation of original contributions and the exchange of knowledge and experience on mechanical and industrial engineering topics like Acoustics and Noise Control, Aerodynamics, Agricultural machinery, Applied Mechanics, Automation, Mechatronics and Robotics, Automobiles, Automotive Engineering, Ballistics, Biomechanics, Biomedical Engineering, Composite and Smart Materials, Composite Materials, Compressible Flows, Computational Mechanics, Computational Techniques, Dynamical Analyses, Dynamics and Vibration, Energy Engineering and Management, Engineering Materials, Fatigue and Fracture, Fluid Dynamics, Fluid Mechanics and Machinery etc.

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Contents

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Life Cycle Analysis and Carbon Credit Earned by Solar Water Heating System

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ABSTRACT

Energetics of a 100 litre per day (lpd) solar water heating system, being used to meet the day-to-day hot water requirement of a typical Indian family, has been studied to estimate the primary energy required in manufacturing process and in maintaining it over an average useful life of the system viz. 10, 15 and 25 years. Energy input values have been calculated for Cu-Cu, Cu-steel, Cu-Al and polypropylene solar flat plate collector type system. The energy payback period and energy yield ratio (EYR) have been calculated. It is observed that Cu-Cu and Cu-steel collector type systems have relatively low embodied energy as compared to Cu-Al collector The EYR increases if the average life of solar water heating system increased as energy required to maintain the system even in most pessimistic case is not much compared to energy saved. Life cycle cost analysis has been carried out to evaluate annualized uniform cost (Rs/kWh) of the system. If this type of project is installed only at 20% of the Indian rural areas then the carbon credit earned by the system is Indian Rs. 2196 crores annually.

Keywords: Cost analysis, energy production factor, energy payback time, carbon credit.

1. INTRODUCTION

Solar water heater is a simple and efficient device, which can be used to heat water without putting any extra burden on precious energy resources. Use of solar water heater as an energy conservation device helps in peak load management in the power plant [1]. In India, the use of solar water heating systems is getting popularity both in domestic and industrial sectors. Collector area of 10, 00,000 m2 had reportedly been installed till the year 2004 [2]. A good manufacturing base has evolved in the country during last two decades for manufacturing solar water heating systems. It is anticipated that by the year 2012, an additional 1 million m2 collector area would be introduced for water heating purposes [3]. Manufacturing of solar water heating systems is expected to require substantial energy inputs. Thus, large-scale dissemination of solar water heating systems may have implications for conventional energy supply systems. Energy analysis of solar water heating systems can provide useful insight towards estimation of energy demand in manufacturing solar water heating system and also their energy payback period. There are a number of studies available about economic viability of the solar water heating systems [4]. No significant work has, however, been reported in the area of energetics of the solar water heating systems in India. This chapter presents the results of the energetic evaluation exercise undertaken on a domestic solar water heating system of 100 litre per day (lpd) capacity. Energy embodied in such systems has been estimated for four most prominent combinations of materials (Cu-Cu,Cu-steel,Cu-Al and polypropylene) used in manufacturing the flat plate absorber of the flat plate solar collector, the main component of the solar water heating system. The life cycle energy outputs of the domestic solar water heating systems had been estimated using RET screen support software [5]. An economic analysis of linear concentrator based and plastic solar water heater was carried out to reduce the initial investment [6-7].

2. COMPONENTS OF A SOLAR WATER HEATING SYSTEM

The main components of the hot water system are flat plate collector and storage tank fixed on the roof of a house with the help of a stand. In India, the Bureau of Indian Standards (BIS) has specified the standards for flat plate collector for a typical output of 100 lpd at 60°C [8]. The flat plate collector used in the system has an absorber plate made up of a material having good thermal conductivity (usually copper, aluminium or steel). The process involved is to make grooves on the absorber plate to place the header-riser structure made up of copper. The grooves on the absorber plate are made to have maximum heat transfer to riser tube due to more area in contact to each other and avoid losses during heat transfer due to poor contact.The risers are of 0.56 mm copper tubes of 12.7 ± 0.5 mm inner diameter and 1.80 m length. In one collector of 2m2, normally 10 risers are used. These risers are placed on the grooves of the absorber plate (normally made up of copper, aluminium or steel sheet). This assembly of absorber plate, headers and risers is coated with either black board paint or with selective coating having high absorptivity and low emittance. The collected heat is transferred to a fluid (normally water) flowing through risers. These risers are connected to headers on both the sides, which are made up of 0.71 mm thick copper tube with 1.10 m length and 25.4 ± 0.5 mm outer diameter having equidistant holes of 12.7 ± 0.5 mm diameter for riser connection using gas welding. The risers are fixed with the absorber plate through soldering to have better mechanical contact with the absorber plate and, thus, having better heat transfer. The absorber plate is generally corrugated to have more surface area for heat collection. This structure is tested for leakage under 5 kg/cm2 pressure. Once the structure passes the pressure test, copper flange of 62 ± 3 mm diameter is connected at all the four sides of headers so that it could be connected with other collector in series or parallel or with GI pipe. The absorber plate is again black painted at the soldered/welded places. This structure is placed in a pre- fabricated box, which is separately made generally using aluminium sheet and has glass wool insulation at the bottom and sides to avoid conductive losses. After the collector plate is fixed in the box, it is covered with a toughened glass on the top and fixed at the installation site with the help of an iron stand grouted firmly on the ground/roof. The flat plate collector, thus, installed is connected with an insulated tank of adequate capacity.

3. LIFE CYCLE ANALYSIS

The negative environmental impact of solar energy systems includes land displacement, and possible air and water pollution resulting from manufacturing, normal maintenance operations and demolition of the systems. However, land use is not a problem when collectors are mounted on the roof of a building, maintenance requirement is minimal and pollution caused by demolition is not greater than the pollution caused from demolishing a conventional system of the same capacity. Another advantage of the system is that, when it reaches the end of its life, almost all materials used in the construction of the system can be recycled which minimizes the pollution of the environment. The pollution created for the manufacture of the solar collectors is estimated by calculating the embodied energy invested in the manufacture and assembly of the collectors and estimating the pollution produced by this energy. The analysis is based on the primary and intermediate embodied energy of the components and materials [9] as illustrated in Fig. 1. In the present analysis no allowance is made for the unit packing, transportation and maintenance as these have insignificant contribution compared to the total.

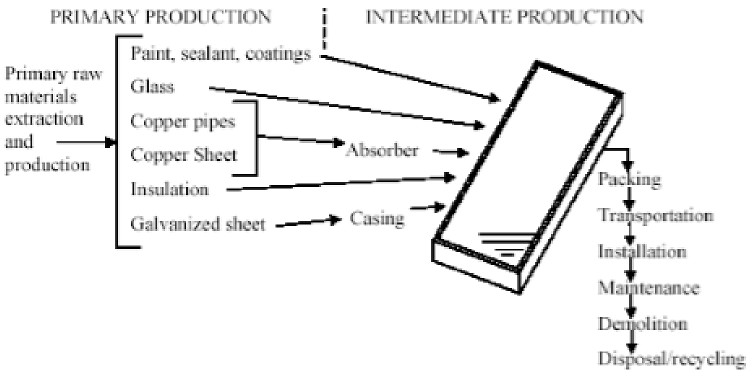


Figure 1: Factors considered in the calculation of embodied energy of a flat-plate collector

The total embodied energy required to produce a complete flat-plate collector is calculated using primary and intermediate production stages. The primary stage is established from an assessment of the various materials used and their corresponding mass. Using the embodied energy index (MJ/kg) defined by Alcorn [10] the material embodied energy content within the unit is determined.

4. METHODOLOGY

Among the three commonly used energetic evaluation methods i.e. energy intensity method, process analysis and input/output based energy accounting method [11], the process analysis method has also been adopted in this study. In this process, individual energy inputs are taken into account by estimating the direct and indirect energy embodied in the system during the entire process of manufacturing the finished good and in maintenance over its useful lifetime. Energy payback period and energy yield ratio are determined to judge the energetic viability of the system. Energy production factor (EPF) is also evaluated on annual basis for eight Indian locations having different weather conditions. Both the input and output energy are taken in equivalent to primary energy terms to facilitate a proper comparison and evaluation. Life cycle cost analysis has been carried out to evaluate annualized uniform cost (Rs/kWh) of the system [12].

4.1 Assumptions

The following simplifying assumptions have been made in the analysis presented in this chapter.

1. Manual labour has not been taken into account in estimating energy input because manual labour does not have impact on primary source of energy during manufacturing the device. Moreover, conversion of manhours into equivalent primary energy may have considerable errors and ambiguities.
2. The parameters charaeterising the thermal performance of the flat plate solar collector (FRY0, FRUL) used for estimation of the energy output have been taken from the literature provided with the device, though verified experimentally through standard tests at Solar Energy Centre, the apex test centre for testing solar energy devices in India.
3. Process analysis has been undertaken upto second level of regression only.

4.2 Energy Embodied

The estimation of energy embodied using process analysis comprises of the following steps:

(a) Identifying the components of the device and the quantity of primary material used in them.

(b) Estimation of the energy embodied in each component.

(c) Estimation of the useful life of the device and each component to determine the energy input during useful life of the device for each of the components.

(d) Estimation of the lifecycle embodied energy of the system.

Energy embodied in the material used in a domestic solar water heating system EE_{mat} can be expressed as:

$$EE_{mat} = \sum_{i=1}^{n} \xi_i m_i \qquad (1)$$

where mi represents the mass/volume of the i^{th} component of the solar water heating system, x i the energy intensity (in MJ per unit mass or MJ per unit volume as applicable) of the material of the i^{th} component and n the total number of components in the system. The numerical values for n and mi's were finalised on the basis of several visits of a manufacturer of domestic solar water heating systems. The corresponding values of x i have been obtained from the literature as shown in Table 1-2.

Table 1 presents the material required in manufacturing a 100 litre per day solar water heating system, and the corresponding embodied energy values for four different types of collectors whereas Table 2 presents the material being used and energy embodied in balance of system of a domestic solar water heater of 100 lpd capacity.

Table 1: Embodied energy in manufacturing of a flat plate collector

Flat plate collector components with headers and risers of copper	**Materials**	**Quantity**	**Unit**	**Energy Intensity (MJ/unit)**	**Embodied energy (MJ)**
Section frame (100mm × 25mm)	Aluminium	4.25	kg	254	1080
Sheet for back of the box (24 swg)	Aluminium	4.5	kg	254	1143
Angle for box (1"× 1" × 16 swg)	Aluminium	1.5	kg	254	381
Foil for heat reflection (0.5 mm)	Aluminium	1.5	kg	254	381
Neelpop rivets (60 nos.)	Aluminium	0.03	kg	254	8
Steel tapping screw	Aluminium	0.5	kg	50	25
Insulation	Glass wool	0.12	m^3	114	14
Glazing (4 mm thick)	Toughened glass	35	kg	30	1050
0.5" diameter riser tube (24 swg 10 nos.)	Copper	4	kg	133	532
1" diameter header tube (22 swg 2 nos.)	Copper	2.25	kg	133	299
Flanges (4 nos. 80 mm outer diameter)	Brass	0.8	kg	133	106
Beading for glass sealing	Rubber	1.5	kg	130	195
Continued Table 1					
Flat plate collector components with headers and risers of copper	**Materials**	**Quantity**	**Unit**	**Energy Intensity (MJ/unit)**	**Embodied energy (MJ)**
Black paint		0.5	kg	72	36
Absorber plate (0.71mm thick)	Aluminium	4.46	kg	254	1132
Absorber plate (34 swg)	Copper	4.25	kg	133	565
Absorber plate (0.71mm thick)	Steel	13	kg	50	650
Total embodied energy for aluminium plate collector (a)					6381
Total embodied energy for copper plate collector (b)					5814
Total embodied energy for steel plate collector (c)					5899
Polypropylene collector with header and risers also of polypropylene		17	kg	150	2550

Table 2: Embodied energy in manufacturing balance of a 100 lpd solar water heating system

System components	**Material**	**Quantity**	**Unit**	**Energy intensity (MJ/unit)**	**Embodied energy (MJ)**
(a) Storage tank					
1. Tank	Stainless steel	1.25	kg	50	625
2 Insulation	Glass wool	0.55 m^3 114 63			
3 Cladding	Aluminium	1.5	kg	254	381
Total (a)					1069
(b) Stand					
1 Angle	Steel	12	kg	50	600
2 Paint		0.5	kg	72	36
Total (b)					636
(c) Pipeline 20'	GI	20	kg	50	1000
1 Insulation	Glass wool	0.14 m^3 114 16			
2. Cladding	Aluminium	0.8	kg	254	203
Total (c)					1219
Grand total (a)+(b)+(c)	2924				

The direct energy input E_{direct} in the manufacturing of the domestic solar water heating system is the direct energy consumed during manufacturing process of the system, such as welding, drilling, cutting, rolling etc.

Energy embodied in periodic replacement and maintenance of a domestic solar water heating system E_{Emain} can be estimated as:

$$EE_{main} = \sum_{i=1}^{n} \left[\frac{UL_{dswh}}{FR_i} - 1 \right]^{+} (\xi_i m_i) \qquad (2)$$

where U_{Ldswh} represents the expected useful life of the domestic solar water heating system and F_{Ri}, the frequency of replacement of the i^{th} component. The '+' sign indicates that for the quantity inside the square bracket, the next higher whole number is taken.

The life cycle embodied energy E_{lc} in the domestic solar water heating system can, therefore, be expressed as

$$E_{lc} = E_{direct} + \sum_{i=1} \xi_i m_i + \sum_{i=1} \left[\frac{UL_{dswh}}{FR_i} - 1 \right]^{+} \xi_i m_i \tag{3}$$

Table 3 presents the life cycle energy embodied in a domestic solar water heater for three collector types and for three different scenarios based on frequency of replacement of the components of the system for 20 years useful life.

Table 3: Life cycle embodied energy in 100 lpd solar water heating system (useful life = 20 years)

Material replacement	Qty	Energy Intensity (MJ/unit)	Optimistic scenario		Most probable scenario		Pessimistic scenario	
		Frequency of replacement (years)		Additional energy input for replacement during lifetime (MJ)	Frequency of replacement (years)	Additional energy input for replacement during lifetime (MJ)	Frequency of replacement (years)	Additional energy input for replacement during lifetime (MJ)
Glass	35 kg	30	10	1050	7	2100	5	3150
Rubber	1.5 kg	130	10	195	7	390	5	585
Paint	1.0 ltr	72	7	144	5	216	3	432
Insulation	$0.81m^3$	114	10	92	7	184	5	276
Total				1481		2890		4443
Annual energy requirement in maintenance				74		145		222
Life cycle embodied energy		For Cu-Cu collector system		10219		11628		13181
		For Al-Cu collector system		10786		12195		13748
		For steel-Cu collector system		10304		11713		13266

4.3 Energy Output

The annual useful energy output of a domestic solar water heating system Eo,u would depend upon a variety of design and operational parameters. These include the thermal performance of the solar flat plat collector and storage tank, solar radiation availability, the operating temperature, the capacity utilisation of the system, inlet water temperature, and ambient conditions. The equivalent primary energy derived/saved by the domestic solar water heating system would also depend upon the characteristics of the energy resource technology combination substituted by the solar water heater. If the fuel substituted has calorific value CV_f and its efficiency of utilisation in the corresponding heating device is η_f then the equivalent primary energy saved by the use of domestic solar water heating system $E_{o,pa}$ can be estimated [5] as

$$E_{o,pa} = \left(\frac{E_{o,u}}{\eta_f} \right) (1 + \alpha_1) \tag{4}$$

where α_1 is the fraction of the process energy required to make the fuel available to the user.

4.4 Measures of Energetic Performance

In this study, two measures of energetic performance: (i) energy yield ratio (EYR) and (ii) energy payback period (EPBT) have been considered for evaluating the energy feasibility of domestic solar water heating system. Energy yield ratio (EYRdswh) is defined as the ratio of the life cycle primary energy output of the domestic solar water heating system to the lifecycle embodied energy, i.e.

$$EYR_{dswh} = \frac{\left[\left(\frac{E_{o,u}}{\eta_f}\right)(1+\alpha_1)\right] UL_{dswh}}{E_{lc}} \quad (5)$$

where UL_{dswh} is the useful life of the domestic solar water heater system. Similarly, the energy payback period, $EPBT_{dswh}$, which is defined as the time required to recover the initial primary energy embodied in the domestic solar water heating system by the net annual primary energy savings due to the use of the solar water heating system, can be expressed

$$EPBT_{dswh} = \frac{(E_{direct} + EE_{mat})}{\left[\left(\frac{E_{o,u}}{\eta_f}\right)(1+\alpha_1)\right] - \left(\frac{EE_{main}}{UL_{dswh}}\right)} \quad (6)$$

While writing the above equation, the life cycle requirement of energy for operation and maintenance of the system has been distributed uniformly over the entire lifetime of the system.

4.5 Energy and Economics Analysis:

4.5.1 Energy Production Factor (EPF):

It is used to predict the overall performance of the system. This is defined as the ratio of output energy and the input energy which predicts the overall performance of the system. It is defined on annual basis [13] as

$$EPF = \frac{E_{out}}{E_{in}} \quad (7)$$

$$\text{or, } EPF = \frac{1}{EPBT}$$

If EPF 1, for EPBT =1 the system is worthwhile it is not worth from energy point of view.

4.5.2 Annualized Uniform Cost (Uncost)

Annualised uniform cost is defined as a product of present value of the system and capital recovery factor (CRF) [9].

$$Unacost = Net\ present\ value \times CRF \quad (8)$$

$$\text{where } CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

and Annual salvage value of the system is calculated as

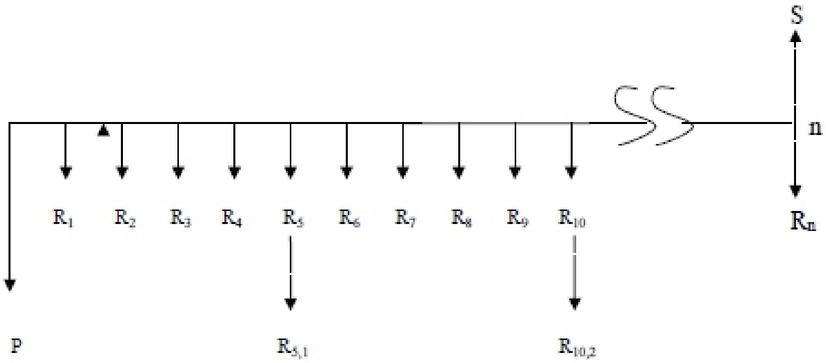
Annual salvage value=Salvage value ×sinking fund factor (SFF) (9)

$$\text{where } SFF = \frac{i}{(1+i)^n - 1}$$

n = no. of years

and i = interest rate per year

Let P is present value and R1, R2…Rn is operational and maintenance per year and R5, 1, R10, 2…Rn, n is black painting, cleaning and glass replacement cost in every five year. Then the net present value is evaluated as,



$$Net\ Present\ value =$$

$$P + R_1 \times \left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]_{i,n} + R_{5,1} \times \left[\frac{1}{(1+i)^n}\right]_{i,5} + R_{10,2} \times \left[\frac{1}{(1+i)^n}\right]_{i,10} + \ldots\ldots\ldots\ldots - S \times \left[\frac{1}{(1+i)^n}\right]_{i,n1} \quad (10)$$

4.6 Results and Discussion

From Table 1 it may be seen that the polypropylene collector is least energy-embodied system followed by steel-Cu, Cu-Cu and Al-Cu in the order of energy embodied. As all the components of the polypropylene collector are made up of polypropylene only, the energy embodied in polypropylene is only taken into account for this type of system. In a solar water heating system usually the absorber plate, outer box, storage tank and stand have long life of 20-25 years, therefore, the life cycle energy embodied have been calculated for three values of the useful life (15, 20 and 25 years). In this useful lifetime, components like glazing, material like insulation, paint may require replacement and, therefore, three different scenarios (optimistic, most probable and pessimistic) have been considered for their replacement and the energy embodied has been calculated for the overall system taking into account this replacement. In the optimistic scenario, the frequency of replacement is the least while in pessimistic scenario, it is quite large. Table 2 gives the embodied energy of domestic solar water heating system 100 lpd capacity.

Figure 2 presents the pie chart of energy embodied in a complete system for different collector type. It may be seen that the energy embodied in polypropylene collector based solar water heating system has the lowest value among all the four systems considered in this study. This is mainly because the collector is not glazed and only polypropylene is used in the collector unlike other collectors where glazing and Al cladding is used. As polypropylene collector type system is yet in the developmental stage and its performance details are yet not available, the lifetime energy analysis of this collector has not available, the lifetime energy analysis of this collector has not been undertaken.

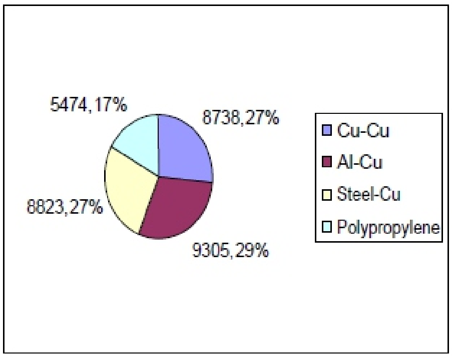


Figure 2: Embodied energy in 100 litre per day solar water heater system with different collector type (MJ)

From Table 3, it is observed that glazing has significant impact on energy embodied. It may be seen that about 25% energy input is there in maintaining the system in the most probable case for a 20-year lifetime of the system. Table 4 presents the EYR for three locations i.e. Delhi, Bangalore and Srinagar having different weather conditions [5].

Table 4: Energy yield ratio (EYR) of 100 lpd solar water heating system

Station	Scenario	Useful life 15 years			Useful life 20 years			Useful life 25 years		
		E_{out} (MJ)	E_{lc} (MJ)	EYR	E_{out} (MJ)	E_{lc} (MJ)	EYR	E_{out} (MJ)	E_{lc} (MJ)	EYR
Delhi	Optimistic	28800	10219	2.84	38400	10219	3.76	48000	11628	4.14
	Most probable	28800	11556	2.49	38400	11628	3.3	48000	13037	3.68
	Pessimistic	28800	13181	2.19	38400	13181	2.91	48000	14662	3.27
Bangalore	Optimistic	70020	10219	6.9	93600	10219	9.15	117000	11628	10.06
	Most probable	70020	11556	6.05	93600	11628	8.05	117000	13037	8.97
	Pessimistic	70020	13181	5.31	93600	13181	7.1	117000	14662	7.98
Srinagar	Optimistic	53650	10219	5.28	78200	10219	7.7	97750	11628	9.62
	Most probable	53650	11556	4.64	78200	11628	6.76	97750	13037	8.45
	Pessimistic	53650	13181	4.07	78200	13181	5.93	97750	14662	7.41

As the weather condition in Delhi is such that hot water requirement is limited to winter season only, the energy output value has been calculated for the period from October 1st to March 15th, while for

Bangalore and Srinagar it has been taken for the entire year. The lower value of energy output in Srinagar as compared to Bangalore is due to relatively poor weather conditions there. The EYR has been calculated for 15, 20 and 25 years of lifetime and for three scenarios i.e. optimistic, most probable and pessimistic case as far as maintenance is concerned. It may be seen that EYR is the best for Bangalore, where hot water is used throughout the year and weather conditions are also almost uniform all over the year. In Srinagar also the EYR is better, as hot water requirement is uniform throughout the year, but due to varying weather condition it is less than Bangalore. Table 5 presents the energy payback period for eight locations in India for two scenarios i.e. (i) for use period from October 1st to March 15 and (ii) use period of 12 months.

Table 5: Energy payback period for 100 lpd solar water heating system

Station	Per year use of SWH (months)	Energy output per annum (MJ)	*Net annual energy output per annum (MJ)	Energy payback period for different collector types solar Water heater for 20 year lifetime(years)								
				Optimistic			Most probable			Pessimistic		
				Cu-Cu	Cu-Al	Cu-Steel	Cu-Cu	Cu-Al	Cu-Steel	Cu-Cu	Cu-Al	Cu-Steel
Delhi	5.3	1920	1804	4.6	5.1	4.9	4.8	5.1	4.9	5.2	5.5	5.2
	12	4050	3934	2.1	2.4	2.2	2.2	2.4	2.2	2.4	2.5	2.4
Bangalore	5.3	2440	2324	3.5	4	3.8	3.7	4	3.8	4	4.3	4
	12	4680	4564	1.8	2	1.9	1.9	2	1.9	2	2.2	2.1
Mumbai	5.3	2000	1884	4.4	4.9	4.7	4.6	4.9	4.7	4.9	5.2	5
	12	3940	3824	2.2	2.4	2.3	2.3	2.4	2.3	2.4	2.6	2.5
Kolkata	5.3	2230	2114	3.9	4.4	4.2	4.1	4.4	4.2	4.4	4.7	4.4
	12	4560	4444	1.9	2.1	2	2	2.1	2	2.1	2.2	2.1
Chennai	5.3	2380	2264	3.6	4.1	3.9	3.8	4.1	3.9	4.1	4.4	4.1
	12	5000	4884	1.7	1.9	1.8	1.8	1.9	1.8	1.9	2	1.9
Allahabad	5.3	2670	2554	3.2	3.6	3.4	3.4	3.6	3.4	3.6	3.9	3.7
	12	5460	5344	1.5	1.7	1.6	1.6	1.7	1.6	1.7	1.8	1.8
Srinagar	5.3	1360	1244	6.6	7.5	7.1	7	7.5	7.1	7.5	7.9	7.6
	12	3910	3794	2.2	2.4	2.3	2.3	2.4	2.3	2.5	2.6	2.5
Shilong	5.3	2060	1944	4.2	4.8	4.5	4.5	4.8	4.5	4.8	5.1	4.8
	12	3650	3534	2.3	2.6	2.5	2.5	2.6	2.5	2.6	2.8	2.7

*** Net energy after deducting the annual energy requirement for maintenance**

The payback period has been calculated for three types of collectors for optimistic, most probable and pessimistic cases. It may be seen that the energy payback period for is 3.2 years for Allahabad if solar water heater is used in winters only taking the optimistic case as regards to maintenance and 7.9 years for Srinagar in 12 months use is as low as 1.5 years in Allahabad for the optimistic case to 2.7 years for Shillong in most pessimistic case. Energy payback period most pessimistic case. Energy payback period is 3.2 years for Allahabad if we use solar water heater in winters only taking the optimistic case as regards to maintenance and 7.9 years for Srinagar in most pessimistic case. Fig 3 presents bar chart of energy production factor (EPF) on annual basis for eight Indian locations having different weather conditions. Figure shows that energy production factor is highest for Allahabad, i.e. 0.46.

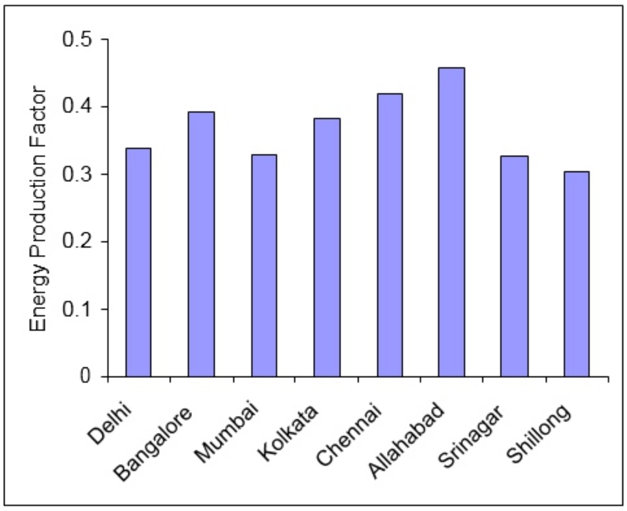


Figure 3: Energy production factor in 100 litre per day solar water heater system for different stations.

Equation. (8-10) have been used for evaluating the annualized uniform cost of the system. The capital cost (P) and Salvage value(S) of solar water heater are shown in Table 6 [13].

Table 6: Capital cost, salvage value and maintenance cost of 100 litre per day solar water heater

Component s of Domestic Solar Water Heater	Qty	Present cost (Rs.)	Salvage value of different components(Ss) at the inflation rate of 4% (Present values of scrap for : Iron @Rs. 15/kg,Aluminium@Rs.80/kg and Copper @Rs.250/kg)		
			After 15 yrs (Scrap value) Iron @Rs. 27/kg Aluminium@Rs144/kg Copper @ Rs. 450/kg	After 20 yrs (Scrap value) Iron @ Rs 33/kg Aluminium@Rs175/kg Copper @ Rs 548/kg	After 25 yrs (Scrap value) Iron @Rs. 40/kg Aluminium @Rs. 214/kg Copper @Rs. 667/kg
Storage tank @ Rs. 90/kg	1.25 kg	113	203	247	300
Glass wool @ Rs. 60/m2	0.55 m3	7260	…..	…..	…..
Al Cladding	1.5 kg	250	…..	……	…...
Steel Stand	12 kg	600	264	396	588
Copper riser @ Rs. 380/kg	4 kg	1520	1800	2192	2668
Copper header	2.25				
@ Rs. 380/kg	kg	855	1013	1233	1500
Al sheet @ Rs. 165/kg	4.5 kg	743	648	788	963
Al angle	1.5 kg	270	216	263	321
Toughened glass 4mm	35 kg	2315	…..	…..	……
Glass wool @ Rs. 60/m2	0.12 m3	1584	….	…..	…..

Continued Table 6

Components of Domestic Solar Water Heater	Qty	Present cost (Rs.)	Salvage value of different components(Ss) at the inflation rate of 4% (Present values of scrap for : Iron @Rs. 15/kg,Aluminium@Rs.80/kg and Copper @Rs.250/kg)		
			After 15 yrs (Scrap value)	After 20 yrs (Scrap value)	After 25 yrs (Scrap value)
			Iron @Rs. 27/kg	Iron @ Rs 33/kg	Iron @Rs. 40/kg
			Aluminium@Rs144/kg Copper @ Rs. 450/kg	Aluminium@Rs175/kg Copper @ Rs 548/kg	Aluminium @Rs. 214/kg Copper @Rs. 667/kg
Al absorber Plate (0.71mm) @ Rs. 165/kg	4.46 kg	736	642	780	955
Cu absorber plate @ Rs 380/kg	4.25 kg	1615	1913	2329	2835
Glass wool for piping @ Rs.60/m2	0.14 m3	1848	…..	…..	…..
Frame, foil, rivets plate etc	5.78 kg	954	833	1012	1237
Polypropylene	17 kg	1000	….	….	….
GI Pipeline	20 kg	1080	443	663	985
Black paint	1 litre	125	….	….	….
Capital cost(Rs)	**22868**	**7975**	**9903**	**12352**	**12352**

Operation, maintenance, black painting and glass replacement cost=Rs 1000/- per yearAnnualised uniform cost (Rs./kWh) of the system are evaluated by considering the life time (n) of the system as 15, 20 and 25 years and money worth is 10% per year. Results shows that the annualized uniform cost in Rs. /kWh decreases with increases in life time of the system. Detailed results are shown in Table 7.

Table 7: Annualised uniform cost on life time basis for n =15, 20 and 25 years.

	Useful life15 years Use per year (months)		Useful life 20 years Use per year (months)		Useful life 25years Use per year (months)	
	5.3	**12**	**5.3**	**12**	**5.3**	**12**
Station	**Annualised uniform cost (Rs./kWh)**		**Annualised uniform cost (Rs./kWh)**		**Annualised uniform cost (Rs./kWh)**	
Delhi	7.06	3.35	6.59	3.12	6.36	3.02
Bangalore	5.55	2.9	5.18	2.7	5.01	2.61
Mumbai	6.77	3.44	6.32	3.21	6.11	3.1
Kolkata	6.08	2.97	5.67	2.77	5.48	2.68
Chennai	5.69	2.71	5.31	2.53	5.13	2.44
Allahabad	5.07	2.48	4.74	2.32	4.58	2.24
Srinagar	9.96	3.47	9.31	3.24	8.98	3.12
Shillong	6.58	3.71	6.14	3.47	5.93	3.35

4.6.1 Carbon Credit:

Carbon Credit Trading (Emission Trading) is an administrative approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. Carbon credits are a tradable permit scheme. A credit gives the owner the right to emit one ton of carbon dioxide. International treaties such as the Kyoto Protocol set quotas on the amount of greenhouse gases countries can produce. Countries, in turn, set quotas on the emissions of businesses. Businesses that are over their quotas must buy carbon credits for their excess emissions, while businesses that are below their quotas can sell their remaining credits. By allowing credits to be bought and sold, a business for which reducing its emissions would be expensive or prohibitive can pay another business to make the reduction for it. This minimizes the quota's impact on the business, while still reaching the quota. Credits can be exchanged between businesses or bought and sold in international markets at the prevailing market price. There are currently two exchanges for carbon credits: (i) the Chicago Climate Exchange and (ii) the European Climate Exchange. In the year 2005, 375 million tons of carbon dioxide equivalents (tCO2e) were transacted at a value of € 3.31 billion with an average price of € 10.56 per ton. In the first three months of 2006, the average reported price of carbon dioxide equivalent was € 16.72 per ton. European and Japanese Companies were the major buyers and China was the major seller of the carbon credits in 2005-06. Demand of carbon credits continued to soar in 2006-07, resulting in an increase in the treaded rate of carbon credits. The present market rate is fluctuating at € 20-22 in the European Climate Exchange (www.europeanclimateexchange.com) [14].

4.6.2 Population in Rural Areas

There are 602 districts and 127800 villages in India based on 2005 statistics and as per 2001 census. Each village has more than 1000 population. Most population of India lives in rural areas. Therefore total population of rural areas was 127.8 million in the year 2001.

Present population is given by the equation [15],

$$P_n = P_0 \times (1+i)^n \qquad (11)$$

where P_n is population in the nth year, P_0 population in the 0th year (the year 2001; P_{2001} =127.8 million) and i is the annual growth rate in the population, which equals to 2%. The rural population in the current year will be as

$$P_{2010} = P_{2001} \times (1+0.02)^9 = P_{2001} \times 1.1951$$

$$= 127.8 \text{ million} \times 1.19151$$

$$= 152.733 \text{ million}$$

$$\text{Then total number of families in rural areas} = \frac{1}{5} \times 152.733 \text{ million}$$

$$= 30.55 \text{ million.} \qquad (12)$$

4.6.3 Carbon Credit Earned by Solar Water Heater:

Total power produced per annum =1224.2 kWh =1.224 Mwh

If the unit cost of electricity at present is 5.5, then,

The cost of energy produced for a single household=1224.2 × 5.5 = Rs. 6733 per annum.

The average CO2 equivalent intensity for electric generation from coal is approximately 0.982 kg of CO2 per kWh at source [16, 17]. However, 40% is transmission and distribution losses and 20% loss is due to the inefficient electric equipment used. Then the total figure comes to be 2.04 kg of CO2 / kWh.

The CO2 (carbon) emission reduction by solar water heater comes to = 1224.2 × 2.04 = 2497.37 kg = 2.5 tons.

If carbon dioxide emission reduction is at present being traded @ € 21/ tons CO_2 , then carbon credit earned by the solar water heating system comes to = USD (2.5 × 30.55 million × 21 × 1.29202) = USD 2072 million per annum (where, 1€ = 1.29202 US dollar as on Jan 2012). Carbon credit earned with variation of household in rural areas is mentioned in figure 4. If this type of project is installed only at 20% of the Indian rural areas then the carbon credit earned by the system is USD 414 million (Indian Rs. 2196 crores) annually.

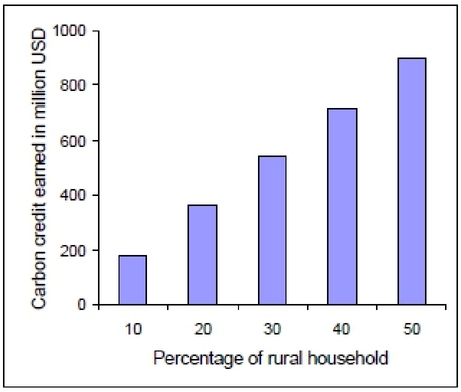


Figure 4: Carbon credit earned with variation of rural household

4.7 CONCLUSIONS:

The following conclusions have been drawn from the above analysis:

1. The polypropylene collector is least energy-embodied system followed by steel-Cu, Cu-Cu and Al-Cu in the order of energy embodied.
2. The EYR is the best for Bangalore, where hot water is used throughout the year due to weather conditions are also almost uniform all over the year.
3. The energy payback period is 3.2 years for Allahabad if solar water heater is used in winters only taking the optimistic case.
4. The energy production factor is least for Shillong i.e. 0.31.
5. The annualized uniform cost in Rs. / kWh decreases with increases in life time of the system.
6. The electricity saved by solar water heating system is Indian Rs. 6733 per annum.
7. The carbon credit earned by solar water heating system is Indian Rs. 2196 crores annually, if the project is installed only at 20% of Indian rural areas.

NOMENCLATURE:

EE_{mat} Energy embodied in the material used in a domestic solar water heater

ξ i Energy intensity of the material of the i^{th} component (MJ/mass or MJ/volume)

n The total number of components in the system

m_i Mass/volume of the i^{th} component of the solar water heating system(kg/m^3)

Ee_{main} Energy embodied in periodic replacement and maintenance of a domestic solar water heating system (MJ)

UL_{dswh} Useful life of the domestic solar water heating system (yrs)

FR_i Frequency of replacement of the i^{th} component (yrs)

E_{lc} Life cycle embodied energy (MJ)

E_{direct} Direct energy input in the manufacturing of the domestic solar water heater (MJ)

$E_{o,u}$ Annual useful energy output (MJ)

$E_{o,pa}$ Equivalent primary energy saved by the use of domestic solar water heating system (MJ)

α_1 Fraction of the process energy required to make the fuel available

EYR_{dswh} Energy yield ratio of domestic solar water heater

$EPBT_{dswh}$ Energy payback period of domestic solar water heater (years)

EPF Energy Production Factor

E_{out} Energy output (MJ)

E_{in} Energy input (MJ)

U_{nacost} Annualised uniform cost (Rs.)

CRF Capital recovery factor

i Interest rate per year

SFF Sinking fund factor

n No. of years

P Present value (Rs.)

$R_1, R_2 \ldots R_n$ Operational and maintenance per year

$R_{5,1}, R_{10,2} \ldots R_{n,n}$ Maintenance and glass replacement cost in every five year

S Salvage value (Rs.)

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An Analysis of Optimum Working Conditions of HCCI Engines

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ABSTRACT

The time when fuel cells are ready for significant use seems to be far off. Therefore it is necessary to find alternative fuels to be used in the standard internal combustion engine to bridge this gap. Simultaneously it is necessary to improve the combustion engine in terms of fuel efficiency and emissions. The necessity to further improve the conventional internal combustion engine is the main challenge scientists and engineers now face. The homogenous charge compression ignition (HCCI) is a promising new engine technology that combines elements of the diesel and gasoline engine operating cycles. As a way to increase the efficiency of the gasoline engine, the attractive properties are increased fuel efficiency due to reduced throttling losses, increased expansion ratio and higher thermodynamic efficiency. The implementation of homogenous charge compression ignition (HCCI) to gasoline engines is constrained by many factors. The main drawback of HCCI is the absence of direct combustion timing control. Therefore all the right conditions for auto ignition have to be set before combustion starts. This paper investigates the past and current research done and considerable success in doing detailed modeling of HCCI combustion. This paper aims at studying the fundamentals of HCCI combustion, the strategy to control the limitation of HCCI engine and finding optimum operating conditions for HCCI engine operation, work on the combustion timing and the engine operating zone for HCCI engines. Four main areas of timing control were identified in an investigation of the available literature: thermal control through exhaust gas recirculation (EGR), variable compression ratio (VCR), variable valve timing (VVT), fuel injection systems and fuel mixtures or additives. To investigate HCCI Combustion Process a detail CFD (Computational Fluid Dynamics) approach will be used to limit the drawback of HCCI Engine.

Keywords: HCCI, Diesel Engine, Combustion, VVT, Fuel Injection, CFD.

INTRODUCTION

The concept of the internal combustion engine is quite old and the main principles have not changed since the times of Rudolf Diesel. Yet there is still room for an improvement. The approaches to reduce the emission, technology changes, such as engine modifications, exhaust gas recirculation, and catalytic after treatment, take longer to fully implement, due to slow fleet turnover. However, they eventually result in significant emission reductions and will be continued through worldwide.. In the commercial vehicle segment, the diesel engine has always been prevalent due to its robustness and unequalled efficiency. In the years to come, however, future emission limits will require the simultaneous reduction of nitrogen oxides (NOx) and particulate emissions to extremely low values throughout most of the world. The approach to alternative combustion processes studies the formation of NOx and soot in the conventional direct injection diesel engine is due to the heterogeneous not premixed combustion characterized by high local temperatures and a local lack of oxygen. With alternative combustion methods, suitable combustion control is applied to avoid the conditions where particulates or NOx are formed.

One alternative for improving engine efficiency and reducing engine emissions is to change the combustion process so as to improve the engine performance. The combustion of a homogeneous air/fuel mixture in the cylinder of a diesel engine is very efficient way to do this. In a sense, the Homogeneous Charge Compress Ignition (HCCI) combustion system merges the advantages of SI engine combustion using a homogeneous mixture and that of a diesel engine with also alternative fuels. The fuel efficiency from the CI engine and the emission levels from the SI engine, and this can be reached with Homogeneous Charge Compression Ignition (HCCI).In the last few years, several studies have shown that the formation of the individual pollutants can be avoided by a far-reaching charge homogenization before combustion and by considerably reducing the combustion gas temperature. One of the method is Homogenous Charge Compressed Ignition (HCCI).

HCCI combustion was first applied to two-stroke engines [1], [2] with improvement in fuel efficiency and combustion stability. When HCCI as applied to the four-stroke engine, the fuel efficiency could be improved up to 50 % co mpared to the SI engine [3].

By analyzing the Internal Combustion engine, transforms the energy obtained in a chemical reaction into mechanical energy. The reaction takes place when a fuel reacts with air, following this equation

$$CH_x + a \cdot (O_2 + 3.77 * N_2) \rightarrow CO_2 + b \cdot H_2O + c \cdot O_2 + d \cdot N_2$$

where CH x denotes hydrocarbures present in the combustible, O2 and N2 are the oxygen and nitrogen present in the air, CO2 ,H2 O,O2 and N2 are the exhaust gas. This reaction is exothermic, so we can obtain energy. The reaction takes place inside a cylinder. This cylinder contains a piston connected to a mechanism of a crank and a crankshaft.

In the SI engine there is a spark discharge close to TDC during the compression stroke. The created flame front expands relatively slowly inside the cylinder until all ignitable mixture is consumed during relatively long burn duration. The fuel has to withstand the increased temperature during the compression stroke and combustion without any self- ignition before the flame front reaches the fuel element. This means that auto ignition resistant gasoline qualities are the primary fuel type for the SI engine. Since the ordinary air- fuel mixture needs to be near stoichiometric for complete flame propagation [4], this usually leads to decreased engine efficiency when the load has to be reduced.

In CI engines, The fuel is injected at high pressure, and air is entrained into the fuel jet. This creates a fuel-rich premixed reaction zone in the central region where soot formation and particulate growth takes place. In the periphery at the turbulent diffusion flame the soot oxidation and NOx formation occurs [5]. The injected fuel amount controls the load, and therefore the CI engine can be operated without a throttle, yielding a further advantage compared to the SI engine. The NOx and soot emissions can be reduced with oxidizing catalysts, NOx traps, Selective Catalytic Reduction (SCR) catalysts and particulate traps. The emission reduction equipment and the high pressure fuel injection system leads to a higher manufacturing cost for the CI engine compared to the SI engine. To overcome these limitations of SI engine and CI engine a blend of twos was developed long ago i.e. Homogeneous charge compression Ignition (HCCI).

HOMOGENEOUS CHARGE COMPRESSION IGNITION (HCCI)

The Homogeneous Charge Compression Ignition (HCCI) engine is often described as a hybrid between the spark ignition engine and the diesel engine. The blending of these two designs offers diesel- like high efficiency without the difficult--and expensive--to deal with NOx and particulate matter emissions. In its most basic form, it simply means that fuel is homogeneously (thoroughly and completely) mixed with air in the combustion chamber very similar to a regular spark ignited gasoline engine, but with a very high proportion of air to fuel i.e. lean mixture. As the engine's piston reaches its highest point (top dead center) on thecompression stroke, the air/fuel mixture auto- ignites from compression heat, much like a diesel engine. The result is the best of both worlds: low fuel usage and low emissions.

Despite advantages, HCCI engines produce high HC and CO emissions as the ignition timing and combustion duration is difficult to control. Therefore, the HCCI operating zone is limited between misfire and knocking. Lack of direct control over ignition initiation is one of the obstacles that need to be addressed. The auto- ignition timing relies on indirect ways such as the air- fuel charge, octane number, temperature, and pressure [6].

Homogeneous charge compression ignition (HCCI) uses a lean premixed air- fuel mixture that is compressed with a high compression ratio. During the end of the compression stroke, ignition occurs through self- ignition in the whole combustion chamber at once. Since the mixture is lean, the maximum temperature, both locally and overall, becomes low compared to other engines, which effectively reduces NOx formation. However, at richer mixtures the combustion becomes too fast and knocking, or ringing, occurs. Therefore, if a higher load is desired, supercharging, or turbo charging is necessary. The load limit (without supercharging) is said to be either the engine structure capabilities (knocking limit) or NOx emissions. The problem with the HCCI engines is related to the lean mixtures, the fast combustion, and the high compression ratio (high engine efficiency) that causes the exhaust temperature to become quite low. This can make it difficult to get both turbo charging and oxidizing catalysts to work. The commercialization of the HCCI engine would require overcoming certain challenges. Low combustion temperatures, though conducive for low NOx emissions, lead to high HC and CO emissions. This is because of incomplete conversion of fuel to Co2 [7] Also, it is difficult to control ignition timing and the rate of combust ion for a required speed and power range [8]. The control over ignition timing is achieved by a spark plug or fuel spray in gasoline engines and diesel engines, respectively. Absence of such mechanisms makes it difficult to directly control ignition in HCCI and therefore, indirect methods are adopted.

HCCI operate well at medium loads but at higher loads combustion becomes intense and rapid [8]. Hence, they operate with lower Indicated Mean Effective Pressure (IMEP) because at higher loads they experience knock. Researchers have proposed to utilize conventional SI operation at high loads and use HCCI for low loads [9]. On the other hand, at very low loads a lean mixture provides inadequate energy and the engine misfires. These two concerns lead to a very constricted operating zone for HCCI.

HCCI combustion is achieved by controlling the temperature, pressure and composition of the air/fuel mixture so that it auto ignites near top dead center (TDC) as it is compressed bythe piston. This mode of ignition is fundamentally more challenging than using a direct control mechanism such as a spark plug or fuel injector to dictate ignition timing as in SI and CI engines, respectively. While HCCI has been known for some twenty years, it is only with the recent advent of electronic engine controls that HCCI combustion can be considered for application to commercial engines. Even so, several technical barriers must be overcome before HCCI engines will be viable for high- volume production and application to a wide range of vehicles.In HCCI mode, combustion initiation has to be controlled indirectly, via in- cylinder temperature at the start of compression. Four main areas of timing control were studied as thermal control through exhaust gas recirculation (EGR), variab le compression ratio (VCR), variable valve timing (VVT), optimizing fuel injection systems and fuel mixtures or additives. The objectives of the study are :

1. With CFD code / simulation program, to evaluate different operation conditions for controlling the combustion timing of HCCI engine by building a detailed model.
2. To evaluate the VCR and VVT timing results for optimizing valve systems.
3. To evaluate fuel mixture and additive for combustion process
4. To analyze the fuel injection systems for HCCI.

5. To obtain combustion stability and analyzing turbulence fluctuations at different parameters , I.e. loads , speeds
6. To estimate soot limit according to latest Euro norms 5 , analyzing NOx emission levels , co, HC at stoichiometric conditions by applying boost pressure / EGR.

ANALYSIS OF OPTIMUM WORKING CONDITIONS FOR HCCI

HCCI research has continued over the past 20 years. HCCI combustion was first discovered as an alternative combustion mode for two-stroke IC engines by Onishi et al. [1979]. They successfully utilized a perceived drawback of "run-on" combustion with high level of residuals and high initial temperature at light load condition to achieve a stable lean combustion with lower exhaust emissions, specifically UHC, and fuel consumption. This new combustion mythology was named "Active Thermo-Atmosphere Combustion" (ATAC). By observing the combustion process in an optical engine they found that during this combustion mode there was no discernable flame propagating through the chamber, indicating combustion occurred as a multi-center auto ignition process. Onishi et al. identified that the critical parameter to obtain ATAC was the initial temperature of the well- mixed charge consisting of fuel, air and residuals.In the same year Noguchi et al. [1979] conducted a spectroscopic analysis on HCCI combustion in an opposed piston, two-stroke engine. They measured high levels of CHO, HO2, and O radicals within the cylinder prior to auto ignition, which demonstrated that pre- ignition chemical reactions had occurred and these reactions contributed to the auto ignition. After auto ignition took place, H, CH, and OH radicals were detected, which were indicative of high-temperature chemical reactions. In a traditional SI engine, these radical species are only associated with end-gas auto ignition, namely knock, which confirmed the similarities between the reactions of HCCI and knock in an SI engine.

To investigate the fuel suitability and broaden the stable operation range for HCCI in two- stroke engines, Lida [1994, 1997] and Kojima and Norimasa [2004] performed a series of experiments using fuels such as methanol, di- methyl ether, ethanol, propane and n-butane to investigate fuel adaptation and the composition and the exhaust mechanism of the exhaust gas. In addition, Honda demonstrated the reliability of HCCI engines in a pre-production two-stroke motorcycle engine [Yamaguchi, 1997]. Based on previous HCCI works in two- stroke engines, Najt and Foster [1983] successfully conducted HCCI experiments in a four- stroke engine with blends of paraffinic and aromatic fuels over a range of engine speeds and dilution levels. The intake air had to be heated to a high level to achieve HCCI operation due to the low level of internal residuals inherent in four-stroke engines.

From simplified chemical kinetically controlled modeling and heat release analysis, they concluded that HCCI combustion is a chemical kinetic combustion process, in which HCCI auto ignition is controlled by the same low temperature (below 1000 K) chemistry as that occurring during SI engine knock and in which most of the energy release is controlled by the high temperature (above 1000 K) chemistry. They realized that HCCI suffers from uncontrolled ignition timing and limited operating range. Thring [1989] extended the work in a four-stroke engine using fully-blended gasoline and mapped the operating regime as a function of equivalence ratio and External EGR rate. The load range limitations of HCCI were noted and an engine operating strategy was put forward, suggesting use of HCCI mode at part load and transitioning into SI flame mode at high load condition.

Experiments have been conducted in four-stroke engines operating on fuels as diverse as gasoline, diesel, methanol, ethanol, LPG, natural gas, etc. with and without fuel additives, such as isopropyl nitrate, di- methyl ether (DME), di-tertiary butyl peroxide (DTBT) etc.. A variety of physical control methods (e.g., EGR) have been examined in an effort to obtain wider stable operation [Odaka et al., 1999; Ryan and Callahan, 1996; Christensen et al., 1997, 1998, 2000; Aceves et al., 1999; Allen and Law, 2002; Nordgren et al., 2004; Caton et al.,2005]. From these investigations and many others in the past five years it appears that the key to implementing HCCI is to control the charge auto ignition behavior which is driven by the combustion chemistry.

Even more than in IC engines, compression ratio is a critical parameter for HCCI engines. Using high octane fuels, the higher the compression ratio the better in order to ignite the mixture at idle or near- idle conditions. However, compression ratios beyond 12 are likely to produce severe knock problems for the richer mixtures used at high load conditions. It seems that the best compromise is to select the highest possible CR to obtain satisfactory full load performance from SI fuels [Najt and Foster, 1983]. The choice of optimum compression ratio is not clear; and it may have to be tailored to the fuel and other techniques used for HCCI control. For early direct- injection diesel- fueled HCCI engines compression ratios must also be limited to mitigate the problem of over advanced auto ignition resulting from pre-ignition chemical reactions [Gray and Ryan, 1997; Ryan et al., 2004; Helmantel et al., 2005]. For these applications other measures should be explored for control of HCCI operation at idle or near idle conditions.Another critical factor to obtain appropriate combustion phasing in HCCI is EGR [Cairns and Blaxill, 2005]. At lower load conditions for HCCI, especially, using high octane number fuels, the effect of internal EGR is to provide sufficient thermal energy to trigger auto ignition of the mixture late in the compression stroke. At higher load conditions for HCCI, especially, using high cetane number fuels cold external EGR is required to retard over-advanced combustion phasing. Effects of external EGR on auto ignition of the mixture are different from that of internal EGR even when both the EGR mixtures are at the same temperature [Law et al., 2002].

In four-stroke engines with flexible valve actuation, there are several strategies for internal EGR. One is the re breathing strategy of Law et al., [2001] where the exhaust valve remains open throughout the intake stroke; another is the exhaust recompression strategy [Zhao et al., 2002]. Milovanovic et al. [2004] demonstrated that the variable valve timing strategy has a strong influence on the gas exchange process, which in turn influences the engine parameters and the cylinder charge properties, hence the control of the HCCI process. The EVC timing has the strongest effect followed by the IVO timing, while the EVO and IVC timing have the minor effects. Caton [2005] showed that the best combination of load range, efficiency, and emissions may be achieved using a re induction strategy with variable intake lift instead of variable valve timing. However, no strategy is able to obtain satisfactory HCCI combustion at near-idle loads. Also, under high levels of internal EGR the emissions are re- ingested in the engine and have an extra chance to be burned in the next cycle.Intake air temperature can be used to modify HCCI combustion phasing, but the controllable range has severe limits. Outside this range the engine volumetric and thermal efficiency are largely reduced due to too advanced auto ignition timing. Also variation of intake temperature is generally a slow process, so this method is not really practical, especially under a transient condition [Sjöberg et. al. 2005]. Increasing cylinder pressure through supercharging or turbo charging is an effective means to increase the engine‟s IMEP and extend the operational range of equivalence ratio for a HCCI combustion mode. Unfortunately, the higher cylinder pressures make auto ignition control at high loads even more critical, which limits its potential application. Christensen et al. [1998] achieved high loads up to 14 – 15 bar and ultra low NOx emissions; and by preheating the intake air CO emission was negligible. However, the typical low exhaust temperatures of HCCI require special care in turbocharger design in order to achieve high load/high efficiency operation. Hyvönen et al. [2003] investigated that the HCCI operation ranges with both mechanical supercharging and simulated turbo charging and compared with a natural aspirated SI with gasoline as fuel. The operating range can be more than doubled with supercharging and higher brake efficiency than with a natural aspirated SI is achieved at the same loads.

An alternative solution to extending operating the range is to operate the engine in a „hybrid mode‟, where the engine operates in HCCI mode at low, medium and cruising loads and switches to spark ignition (SI) mode (or diesel mode-CI) at cold start, idle and higher loads [Milovanovic et al., 2005].Urushihara et al. [2005] used SI in a stratified charge to initiate autoignition in the main homogeneous lean mixture eliminating the need to raise the temperature of the entire charge. A higher maximum IMEP was achieved with SI-CI combustion than with conventional HCCI combustion. However, nitrogen oxide (NOx) emissions increased due to the SI portion of the combustion process.

Spark ignition has also been used for affecting the HCCI combustion initiation. For the same combustion phasing, compression ratio and inlet air temperature can be decreased with spark assistance. The effect from spark assistance decreases with decreasing equivalence ratio (φ) and can be used low to about φ = 0.333 [Kontarakis et al., 2000; Hyvönen et al., 2005]. Recent advances in extending the operational range have utilized stratification at all three parameters: fuel, temperature and EGR. Fuel injection system determines mixing effect of fuel, air and EGR. For gasoline a conventional PFI injection system can form a good homogeneous mixture [Kontarakis et al., 2000]. Fuel stratification can extend the HCCI low and high load limit. Additionally, by a direct injection accompa nied with exhaust recompression strategy [Willand et al. 1998], the fuel injected into exhaust prior to the intakeprocess will undergo pre- ignition reactions and thus promote whole chemical reaction system. As a consequence, the operational range can be extended toward low load conditions. However, the stratified mixture resulting from late injection leads to more NOx and even PM formation. Stratification of fuel is absolutely necessary for HCCI using diesel type fuels, at high load conditions. Although the HCCI combustion of diesel type fuels can be more easily achieved than with gasoline type fuels because of the diesel fuels‟ lower auto ignition temperature, overly advanced combustion timing can cause low thermal efficiency and serious knock at high load conditions. In addition, mixture preparation is a critical issue. There is a problem getting diesel fuel to vaporize and premix with the air due to the low volatility of the diesel fuel [Christensen et al., 1999; Peng et al., 2003]. Many of investigators [Ryan and Callahan,1996; Christensen et al., 1999; Helmantel and Denbratt, 2004; Ra and Reitz, 2005] have indicated the potential for HCCI to reduce NOx and PM emissions. However, premixed HCCI is not likely to be developed into a practical technique for production diesel engines due to fuel delivery and mixing problems.

This has led to the consideration of alternative diesel- like fuel delivery and mixing techniques, such as early direct- injection HCCI and late direct-injection HCCI, which produce a stratification of equivalence ratio. Early direct- injection has been perhaps the most commonly investigated approach to diesel- fueled HCCI. By appropriate configuration of the cylinder, fuel mixing with air and EGR can be promoted. However, the injector must be carefully designed to avoid fuel wall wetting, which can result in increased UHC emissions and reduced thermal efficiency [Akagawa et al., 1999]. If mixing is not achieved, NOx and PM formation will be enhanced. Combustion phasing remains a critical issue in this kind of HCCI. The UNIBUS (UNIform BUIky combustion System) using early direct- injection, which was introduced into production in 2000 on selected vehicles for the Japanese market, chose a dual injection strategy [Yanagihara, 2001]. Su et al. [2005] used multi- injection modes. The injection rate pattern, the mass ratios between pulses and the pulse number have been proved to be very important parameters in achieving acceptable results.

One of the most successful systems to date for achieving diesel- fueled HCCI is late- injection DI-HCCI technique known as MK (modulated kinetics) incorporated into their products of the Nissan Motor Company. In the MK system, fuel was injected into the cylinder at about 3 CAD ATDC under the condition of a high swirl in the special combustion chamber. The ignition delay is extended by using high levels of EGR [Mase et al. 1998; Kimura et al., 2001].The effectiveness of combustion retardation to reduce pressure-rise rates increases rapidly with increasing temperature stratification. With appropriate stratification, even a local stoichiometric charge can be combusted with low pressure-rise rates. Sjöberg et al. [2005] suggested that a combination of enhanced temperature stratification and moderate combustion retardation can allow higher loads to be reached, while maintaining a robust combustion system. The effect of EGR stratification also takes a role in enhancing stability through fuel and temperature stratifications. Controlling the coolant temperature also extends the operational range for a HCCI combustion mode [Milovanovic et al., 2005]. Additionally, Since MTBE and ethanol have low cetane numbers, two additives mixing in diesel fuel could delay overly advanced combustion phasing [Akagawa et al., 1999]. Moreover, water injection also improved combustion phasing and increased the duration of the HCCI, which can be used to extend the high load limit [Nishijima et al., 2002]. However, UHC and CO emissions increased for all of the cases with water injection, over a broad range of water loading and injection.A multi-pulse injection strategy for premixed charge compression ignition (PCCI) combustion was investigated in a four- valve, direct- injection diesel engine by a computational fluid dynamics (CFD) simulation using KIVA-3V code coupled with detailed chemistry[14]. The effects of fuel splitting proportion, injection timing, spray angles, and injection velocity were examined. The mixing process and formation of soot and nitrogen oxide (NOx) emissions were investigated as the focus of the research. The results showed that the fuel splitting proportion and the injection timing impacted the combustion and emissions significantly due to the considerable changes of the mixing process and fuel distribution in the cylinder. While the spray, inclusion angle and injection velocity at the injector exit, can be adjusted to improve mixing, combustion and emissions, appropriate injection timing and fuel splitting proportion must be jointly considered for optimum combustion performance.

Many Numerical and experimental investigations were presented with regard to homogeneous- charge compression- ignition for different fuels. In one of the dual fuel approach, N-heptane and n-butane were considered for covering an appropriate range of ignition behaviour typical for higher hydrocarbons[15].Starting from detailed chemical mechanisms for both fuels, reaction path analysis was used to derive reduced mechanisms, which were validated in homogeneous reactors and showed a good agreement with the detailed mechanism. The reduced chemistry was coupled with multi zone models (reactors network) and 3D-CFD through the Conditional Moment Closure (CMC) approach.In

2002 a study introduces a modeling approach for investigating the effects of valve events In a model based control strategy, to adapt the injection settings according to the air path dynamics on a Diesel HCCI engine, researcher complements existing air path and fuel path controllers, and aims at accurately controlling the start of combustion [16]. For that purpose, start of injection is adjusted based on a Knock Integral Model and intake manifold conditions Experimental results were presented, which stress the relevance of the approach.

A study introduced in 2002 which introduced a modeling approach for investigating the effects of valve events HCCI engine simulation and gas exchange processes in the framework of a full-cycle HCCI engine simulation[17]. A multi-dimensional fluid mechanics code, KIVA-3V, was used to simulate exhaust, intake and compression up to a transition point, before which chemical reactions become important. The results are then used to initialize the zones of a multi- zone, thermo-kinetic code, which computes the combustion event and part of the expansion. After the description and the validation of the model against experimental data, the application of the method was illustrated in the context of variable valve actuation. It has been shown that early exhaust valve closing, accompanied by late intake valve opening, has the potential to provide effective control of HCCI combustion. With appropriate extensions, that modeling approach can account for mixture in homogeneities in both temperature and composition, resulting from gas exchange, heat transfer and insufficient mixing.

Simulations of combustion of direct injection gasoline sprays in a conventional diesel engine were presented and emissions of gasoline fueled engine operation were compared with those of diesel fuel [18]. A multi-dimensional CFD code, KIVA-ERC-Chemkin, that is coupled with Engine Research Center (ERC)-developed sub- models and the Chemkin library, was employed. The oxidation chemistry of the fuels was calculated using a reduced mechanism for primary reference fuel, which was developed at the ERC. The results show that the combustion behavior of DI gasoline sprays and their emission characteristics are successfully predicted and are in good agreement with available experimental measurements for a range of operating conditions. It is seen that gasoline has much longer ignition delay than diesel for the same combustion phasing, thus NOx and particulate emissions are significantly reduced compared to the corresponding diesel cases. The results of parametric study indicate that expansion of the operating conditions of DI compression ignition combustion is possible. Further investigation of gasoline application to compression ignition engines is recommended.

Three-dimensional time-dependent CFD simulations of auto ignition and emissions were reported for an idealized engine configuration under HCCI- like operating conditions [19]. The emphasis is on NOx emissions. Detailed NOx chemistry is integrated with skeletal auto ignition mechanisms for n-heptane and iso-octane fuels. A storage/retrieval scheme is used to accelerate the computation of chemical source terms, and turbulence/chemistry interactions were treated using a transported probability density function (PDF) method. Simulations include direct in-cylinder fuel injection, and feature direct coupling between the stochastic Lagrangian fuel-spray model and the gas-phase stochastic Lagrangian PDF method. For the conditions simulated, consideration of turbulence/ chemistry interactions is essential. Simulations that ignore these interactions fail to capture global heat release and ignition timing, in addition to emissions. For these lean, low-temperature operating conditions, engine-out NOx levels are low and NOx pathways other than thermal NO are dominant. Engine-out NO2 levels exceed engine-out NO levels in some cases. In-cylinder in homogeneity and unmixedness must be considered for accurate emissions predictions. These findings are consistent with results that have been reported recently in the HCCI engine literature.Determining the effects of EGR on HCCI engine operation is just one of many automotive applications that can be modeled with CHEMKIN-PRO‟s HCCI Combustion Model. For the user needing more accurate emission results, the Multi- zone model allows specifying non- uniform initial conditions and heat transfer for regions within the cylinder[20].

In 2007 research [21] demonstrated the relevance of motion planning in the control of the coupled air path dynamics of turbocharged Diesel engines using Exhaust Gas Recirculation. For the HCCI combustion mode, very large rates of burned gas need to be considered and proven on realistic test-bench cases that the proposed approach can handle such situations. Despite strong coupling, the air path dynamics has nice properties that make it easy to steer through control strategy. Its triangular form yields exponential convergence over a wide range of set points. It can also be shown, through a simple analysis, to satisfy operational constraints, provided transient are chosen sufficiently smooth.

A storage/retrieval technique for a Stochastic Reactor Model (SRM) for HCCI engines was suggested [22]. This technique enables fast evaluation in transient multi-cycle simulations. The SRM uses detailed chemical kinetics, accounts for turbulent mixing and convective heat transfer, and predicts ignition timing, cumulative heat release, maximum pressure rise rates, and emissions of CO, CO2, unburnt hydrocarbons, and NOx. As an example, research shown that, when coupled to a commercial 1D CFD engine modeling package, the tabulation scheme enables convenient simulation of transient control, using a simple table on a two- dimensional parameter space spanned by equivalence ratio and octane number. It was believed that the developed computational tool will be useful in identifying parameters for achieving stable operation and control of HCCI engines over a wide range of conditions. Furthermore, a tabulation tool enables multi-cycle and multi-cylinder simulations, and thereby allows studying conveniently phenomena like cycle-to-cycle and cylinder-to-cylinder variations. In particular, simulations of transient operation and control, design of experiments, and optimization of engine operating parameters become feasible.

THE SCOPE FOR FURTHER STUDY

The scope further to be concentrate on the various combustion timing issue. In order to investigate the timing control mainly should concentrate on thermal control through exhaust gas recirculation (EGR), variable compression ratio (VCR), variable valve timing (VVT), fuel injection systems and fuel mixtures or additives. Exhaust gas recirculation (EGR) is the process of recycling exhaust gases and adding them to the intake air. With EGR it is possible to control temperature, mixture, pressure, and composition. In comparison to the other control methods EGR is relatively simple, which is a great benefit. EGR can produce more power in an engine because more fuel could be pumped into the cylinder without spontaneous ignition due to the relative inertness of the emissions gas compared to air. It also could be used to control individual cylinder performance. To accomplish the set objectives, the plan of study is as follows:

1. Concept Generation:

In concept generation phase should develop as many concepts as possible so that various parameter like, compression ratio, intake/exhaust temperature, intake mass, intake air pressure, composition could be controlled. With the generation of different concept a CFD simulation will be carried out to study the effect of various parameters on engine performance. A few degrees of difference in intake temperature can have significant effects on combustion strength. By varying intake temperatures for individual cylinders, combustion could be controlled.

2. Concept Selection:

Once brainstorming and concept generation was completed, then to move on to concept of selection to evaluate different designs based on feasibility and expected results.

3. Engineering Design Parameter Analysis:

To determine design parameters of all the necessary components, CFD analysis will be done.

A 3D model will be set up using a CFD package to determine the effect of different techniques applied for improving the combustion of HCCI engine.

CONCLUSIONS AND RECOMMENDATIONS

As number of concepts will be considered in the analysis which could potentially control variations. Hence by evaluating the various results and finding the appropriate conclusion should be conclude the best strategy for combustion process of HCCI engine.

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Reactions of Industrial Loads and Their Compensation Schemes

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ABSTRACT

Industrial loads which draw power from the grid network of a utility cause repercussions in the network which lead to additional losses in the generation and transmission systems and interfere with the supply of energy to other customers. Such loads have low power factor, produce voltage fluctuations, create unbalances in the system, generate harmonics and produce flicker problems. . Interference due to power system reaction has become greater with the increased use of power electronics, especially to the variable speed converter drives. Compensating equipment which included: switched shunt capacitors, filter banks and static compensators are used to reduce these reactions. The paper analyses the different reactions of various industrial loads and suggests compensation schemes by which these can be reduced to acceptable levels.

1. INTRODUCTION

Industrial loads which draw power from the grid network of a utility cause repercussions in the network which lead to additional losses in the generation and transmission systems and interfere with the supply of energy to other customers. Such loads have low power factor, produce voltage fluctuations, create unbalances in the system, generate harmonics and produce flicker problems. Some of these loads are metal industries having arc furnaces, foundries and rolling mills, cement industries, mining industries, paper mills, chemical plants involving electrolysis process. Interference due to power system reaction has become greater with the increased use of power electronics, especially to the variable speed converter drives. As per the utility regulations the reactions of industrial load on the utility supply had to be reduced to acceptable level. This job is done by compensating equipment which includes: switched shunt capacitors, filter banks and static compensators.

The paper analyses the different reactions of various industrial loads and suggests compensation schemes by which these can be reduced to acceptable levels.

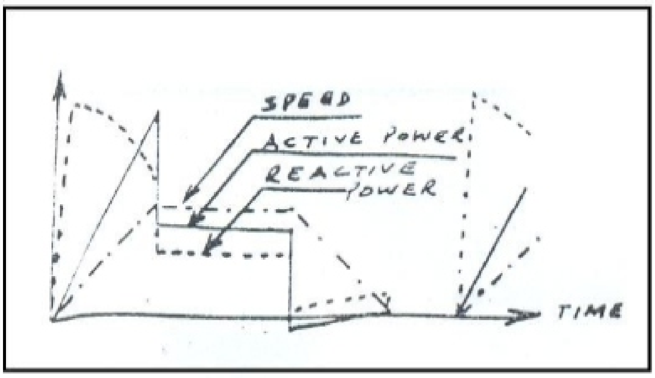
2. POWER SYSTEM REACTIONS OF REACTIONS.

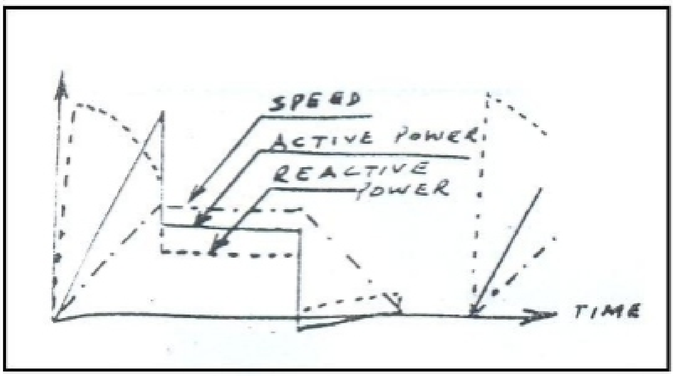
A distinction has been made between the different types of reactions

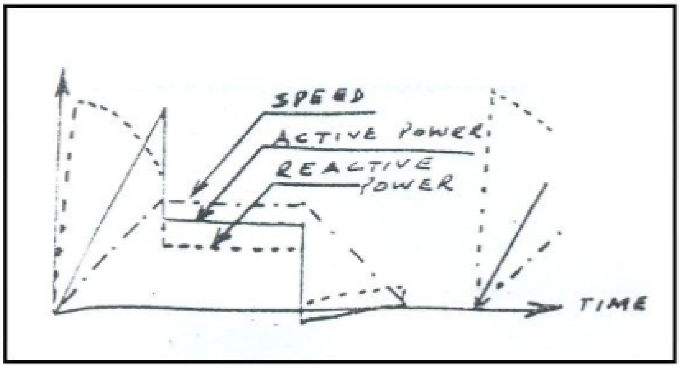
2.1 Deterioration in the powe r factor due to reactive loads

Large varying loads have large and abrupt changes in the profile of real and reactive power. The reactive power consumed by the loads cause additional losses in power generation and transmission systems. The utilities, therefore, impose the restriction of power factor limit on the industrial load and charge penalty if the average power factor over a prespecified period falls below a fixed value(usually 0.9 lag). The changes in the real and reactive power in an arc furnace are caused by variation in the operating points which is defined by arc voltage and the electrode current. The phenomenon makes the reactive load vary between zero and furnace short circuit power and give rise to flicker. The power factor of an arc furnace varies within a range of 0.65 to 0.9.

In a rolling mill, during acceleration and deceleration periods of the mill which lasts between 5 to 20 seconds approximately, the reactive power consumption vary greatly while during period of constant speed, the active and reactive power consumption remains constant as depicted in Fig 1.







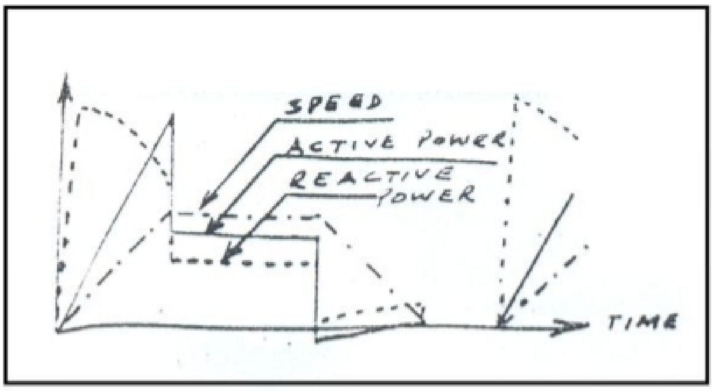
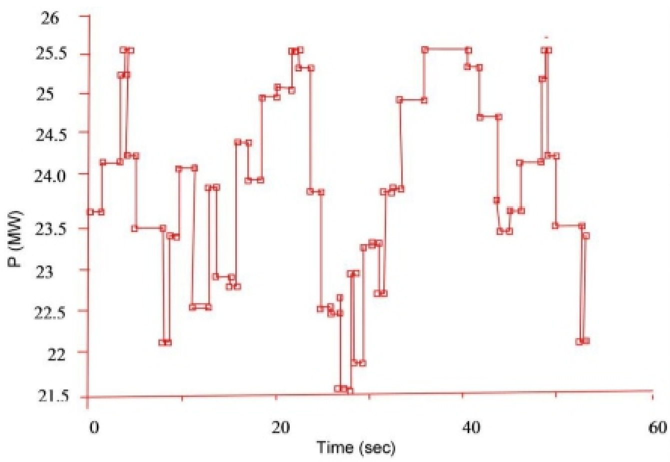
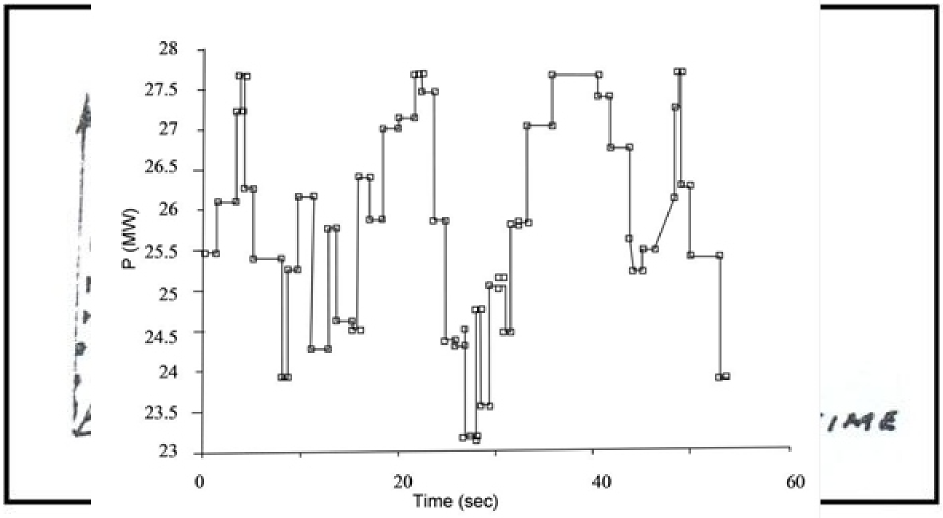


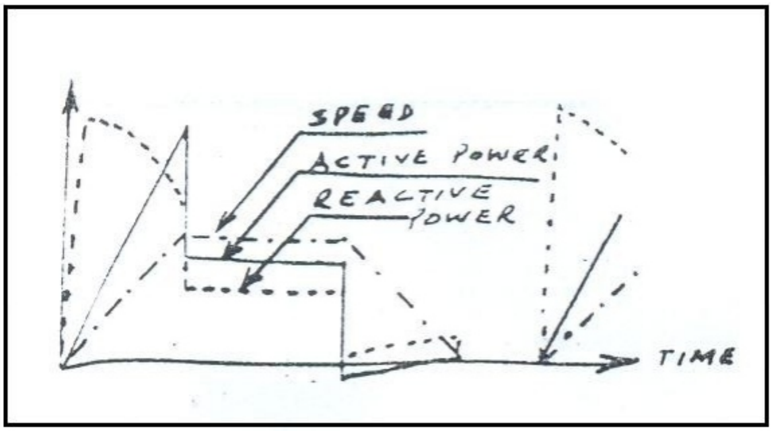
Fig 1 Active and Reactive power variation of a typical rolling mill

Large static converters are used in chemical industry and in electrolysis. Variable speed drives are the most important area of application of power electronics in the light and heavy manufacturing industries, trend being toward ac drives. Converters and ac drives consume large reactive power causing low power factor.Asynchronous motors, which constitute the vast majority of motor drives in industrial plants are responsible for large reactive powerdemands. Motors running at low loads have poorer power factor. The situation can be improved by using synchronous motors which can be operated at unity power factor or with the slightly leading lower factor. However, only drives with medium to high rating are of any real practical use. Typical examples are of large blowers, rotary and reciprocating compressors, pumps and wood grinding machines in paper and pulp plants.

Power factor correction usually relates to balancing of the reactive power drawn by the load from the supply system to an acceptable level on an average basis. The reactive power requirement of most loads is usually slowly variable and can be corrected by a balanced three phase compensator.







A typical load cycle curves for the active and the reactive power requirement of a modern steel mill are shown in fig 2(a) and 2(b), respectively. If such a system is left uncompensated, it will lead to very poor power factor and voltage regulation. Under such circumstances a combination of a static capacitor and a static compensator is required. A scheme for such compensation is discussed later.

2.2 Voltage Fluctuations

Voltage fluctuations typically result from the connection of a load, or combination of Loads, which is relatively large compared with the strength of the supply system, and whose current varies rapidly at the low power factor. Examples are electrical arc furnaces, motor starting, cyclic loads such as mine winders/ rolling mills and reversing drives, in metal and mining industries.

For the purpose of simple analysis, any supply system can be reduced to a constant voltage behind single equivalent impedance, fig 3. The maximum voltage change ΔV, due to a disturbing load, is an approximate function of system reactance and reactive component of current change, i.e., per unit voltage change can be predicted as:

$$\Delta V/V = Iq\ X/V = VIq\ X/V2 = Q/S$$

Where Q(=VIq) is the maximum reactive power change of load and S(=V2/X) is the maximum short circuit level of the supply system at the point of common coupling (pcc) with other consumers, which is where utilities tend to access voltage fluctuation disturbances.

For thyristor converter drives, ΔV can be predicted using equation (1) from the Q of the converter or combination of the converters, as the case may be. In electrical arc furnaces, the voltage fluctuations are caused by the unstable nature of the arc furnaces. Changes in impedance are continuous and predominantly sudden and random; the resultant „modulation" of 50 Hz voltage, when applied to electrical lamps causes „flicker" in their light output.

Voltage fluctuations have unpleasant consequences both for the plant operator"s own installation and for the others connected to the same network.

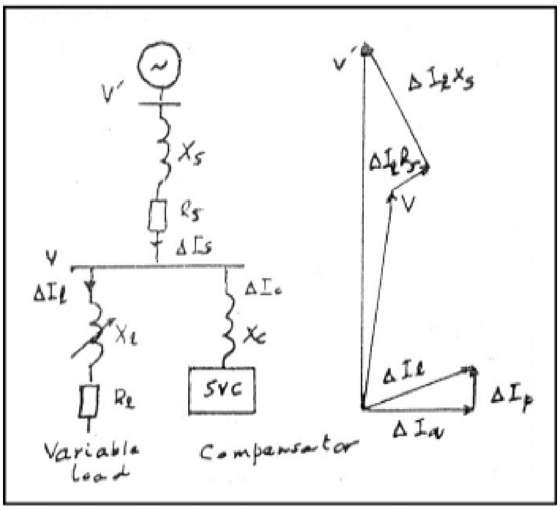


Fig 2 Equivalentcicuit and phasor diagram of a supply network of an industrial load

2.2.1 Voltage Fluctuation Limits

Electrical plant such as control equipment, is usually affected by the step type of voltage fluctuation, and limits can be defined in terms of absolute voltage change. In UK, the step type of fluctuations (rise time less than 100 m/s) due to colliery winders and rolling mills are limited to 1 %,but 3% is permissible if the voltage change is ramped over a period of two seconds. These limits apply when the pcc is 66kV or lower; they are reduced at higher voltages, 0.7% and 0.5% at 132 kV and 220kV, respectively. In case of welders the acceptable voltage fluctuation level lies between 0.25% and 1% depending on the frequency of fluctuations. In case of random fluctuations due to the arc furnaces the criteria of acceptability is by cumulative effect gauge point value. The short circuit voltage depression (scvd) at the pcc should be less than 0.02 at 132kV and below, or 0.016 at 220 kV and above [2].

2.2.2 Reduction of voltage fluctuations

For a given installation, ΔV can be reduced by reducing either load current variations or system reactance, Fig3. System reactance can be reduced by transferring the pcc to a higher short-circuit level (usually at higher voltage) or by strengthening the existing pcc with additional lines, transformers and/or generation.

Alternatively, the reactive current drawn from the supply can be reduced by changes to, or compensation of, the load itself. Examples of the first method are reducing the rated power or increasing the reactance of the arc furnace, and applying current limit to, or deliberately ramping the current demand of a thyristor converter. The disadvantage of such a method is an increase in cycle time and corresponding decrease in production. The second method, that of „compensating" the var demand of the load rapidly, is the use of static compensation better controlled reactors with fixed capacitors or thyristor switched capacitors.

2.3 Unbalanced loads

Most A.C power systems are three phase and are designed for balanced operation. However, some loads, like single phase traction loads and arc furnace loads lad to unbalanced operation of the power system. Unbalanced loads result in different voltage drops across the power system reactances and therefore unequal voltages in the network.

A single phase active power causes the value of the phase- to- phase voltage to which the loaded phase is connected to only change insignificantly ; however, it causes the other phase- to-phase voltages to either increase or decrease, fig4(a). In contrast to this a single phase reactive load results in a corresponding drop in the phase-to-phase voltage which the loaded phase is connected, and a much lower drop in two other phase-to-phase voltages, fig 4(b).

Unbalanced loads have to be balanced in order to obtain once more a voltage delta with both the sides at the coupling point. This job of balancing is done by a compensator.

Excess reactive load in a phase can be balanced by additional capacitor in that phase. Excess active load in a phase balanced by connecting a capacitive load to one of the two remaining phase-to- phase system voltages and an inductive load to the other(voltage increase in one phase and voltage decrease in the other). The load compensation is provided in such a manner that the system does not experience any unbalance load effects.

Harmonics

The connection of non- linear loads to the supply system leads to the production of harmonic currents which may cause current and voltage distortion throughout the network. Fourier analysis can be used to describe distortion in terms of fundamental frequency and harmonic components. In industrial loads, controlled converters (e.g. rolling mills and mill winders) or uncontrolled converters (e.g. aluminium smelters), traction loads and discharge lighting, etc. generate harmonics.

In converters, the switching action of the diodes/thyristors causes a current to be driven from the supply system which is distorted from the desired sine wave. In the steady state the typical harmonics occurring in an ac/dc converter and n=k. p±1, where k=1,2,3…..and p is the pulse number, which depends on the rectifier circuit(usually p=6, although for higher ratings p may be equal or greater than 12). The amplitude of a harmonic is given by

$$I_n = [1/n]\ I_1 F_n$$

Where I_1= amplitude of fundamental wave, n= harmonic number, and F_n = correction factor and depend upon both the control angle and overlap angle. These harmonics are called the characteristic harmonics. Transient conditions and unbalanced operation of the system also causes non-characteristic harmonics-multiples of 3. Fig 5 shows the magnitudes of harmonics of a six-pulse converter.

The arc furnaces are non- linear loads and the presence of erratic non-conductive half cycles explains the appearance of even and odd harmonic currents with lower order and higher magnitude. Assuming an arc furnace to be a current generator of harmonics, the harmonicsgenerated will comprise of line spectrum and a continuous spectrum. Fig 6 shows the harmonic spectrum for a typical furnace.

Harmonic measurements done or six different arc furnace loads in Madhya Pradesh indicated the following type and magnitude of harmonics [2]: 2[2-14]%; 3[4.4-14.9]%; 4[0.2-1.6]%; 5[4.5-12.6]%; 6[0.5-2.8]%; 7[0.3-5.7]%; 8[0.3-0.8]%; 9[0.5-1.1]%.

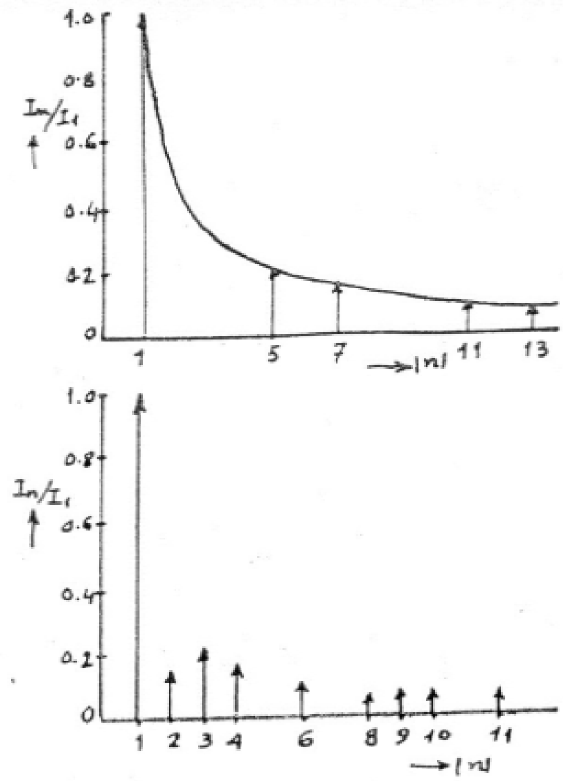


Fig5 Harmonic spectra of a six pulse converter (a) characteristics harmonics, and (b) non characteristics harmonics,

3 . STATIC COMPENSATING SYSTEMS AND FILTER BANKS

Modern static compensators employ static equipment such as capacitors. Reactors and thyristor controlled elements with high speed, electronic measurement and controlled devices as their main components. The two types of compensators normally employed for the industrial applications are: thyristor controlled reactors + fixed capacitors, and thyristor switched capacitors. Depending on the type of requirements of compensation, single phase or three phase (average) control may be used. Some details of these compensators are given in references [1, 3].

In combination with the compensators or otherwise, filter banks are used to provide capacitive reactive power and eliminate harmonics. In filter, an inductive coil (reactor)is put in series with a capacitor, which is tuned to a harmonic frequency. The harmonic current flow into the filters and does not affect the other parts of the plant or network. A filter bank is normally designed so that each of lower harmonic has an individual circuit and the higher harmonics a common high pass filter[3].

The network reactions described do not necessarily infer the need for compensation. The determinant factor is the extent of these reactions, which depends largely upon the ratio of power rating of the load causing the disturbance to the Short-Circuit level of the network at the point of common coupling. In case, an industry installs a separate transformer for their loads, the secondary of this transformer is then isolated from the other transformers and the disturbance effect is reduced due to much higher short circuit reactance at the higher mains voltage level.

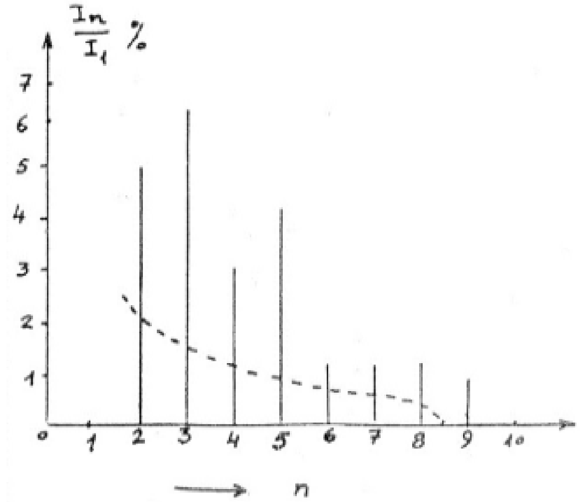


Fig 6 Harmonics spectra of atypical arc furnance

4. TYPICAL LOADS, REACTIONS AND TYPES OF COMPENSATION

Electrical steel plants-

Arc furnace reaction: low pf, voltage fluctuations, unbalance and harmonics

Compensation: filters and static compensators

Rolling mills-

Converter fed d.c. drives

Reaction: low pf, voltage fluctuations, harmonics

Compensation: filters and static compensators

Cement works –

All types of drives

Reaction: low pf and harmonics

Compensation: switched capacitors and filters

Paper mills-

Converter fed drives and asynchronous motors Reaction: low pf and harmonics Compensation: switched capacitors and filters

Chemical plants-

Converters

Reaction: low pf, voltage fluctuation and harmonics Compensation: filters and static compensators

Mining industry-
All types of drives

Reaction: low pf and harmonics Compensation: switched capacitors and filters

5. STATIC COMPENSATOR FOR VSP

Visakhapatnam steel plant(vsp) is an integrated steel plant in Andhra Pradesh, and is connected to APSEB grid at 220 kV, but it has its own generation of about 200MW, sufficient for its own demand. In one of the areas, called Medium Merchant and Structural Mill(MMSM), there are two types of loads- fluctuating and non- fluctuating. The fluctuating loads comprise thyristor converter fed d.c. main motor drives, and the non-fluctuating loads are auxiliary drives, ventilation and others. Both the loads are supplied separately at 11kV from a 220 kV/11 kV transformer. The load cycles, P and Q of one of the operation of the fluctuating load are shown in Fig 2(a) and 2(b). To get an overall pf of 0.9 under all operating conditions, and to limit the voltage fluctuations and harmonics within limit, a fixed capacitor bank of 10 MVAr on non- fluctuating load bus and a static compensator of 10 MVAr(cap)/5MVAr(ind) on the fluctuating load bus have been provided. The capacitive part of the compensator has been provided in the form of four filter banks, tuned to 5th,7th , 11th, and 13th harmonics. The compensator scheme is shown in fig 7. The compensator limits the voltage fluctuations within 2% for slow change of 2 per 50 seconds and within 0.7% for fast changes of 2 per second. The filters limit the individual harmonic voltage distortion to 3% and total harmonic voltage distortion to 4%.

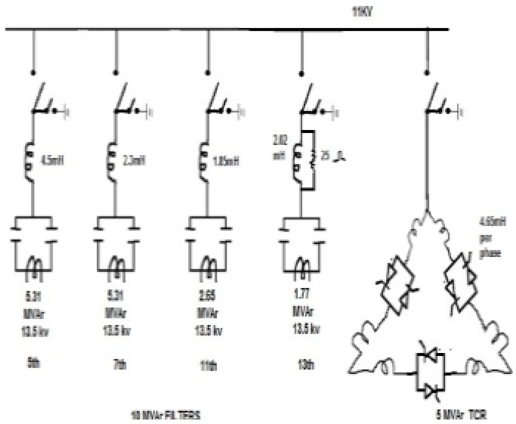


Fig. 7 : Static compensator at VSP network

6. FILTER BANKS FOR SALEM STEEL PLANT

When a load consumes nearly constant reactive power, but at the same time produces harmonics, giving rise to voltage distortion, the use of filter bank is the most desirable method of compensation. A filter banks combination of 10MVAr at 11 kV was installed at salem steel power plant. The filter bank consists of 5^{th}, 7^{th}, 11^{th}, and 13^{th} harmonic filters, Fig 8.With these filter banks , the power factor was improved from 0.3 to 0.9 and the voltage harmonic distortion was reduced from 3.4% to 0.8 %. The voltage wave form at 11kv bus with and without filter bank is shown in fig. 9.

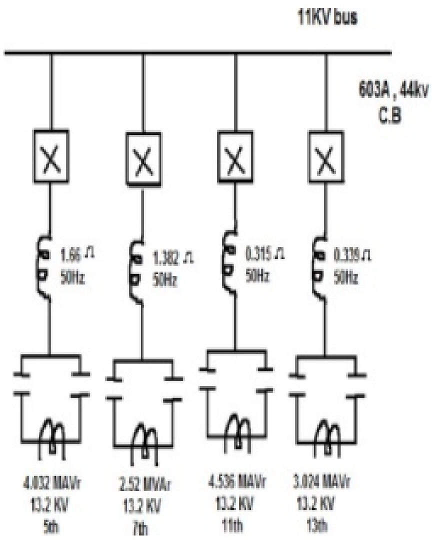


Fig 8 Filter banks at salem steel plant

SUMMARY

It is desirable to be aware of the disturbing effects of different types of industrial loads. The major reactions of considerations are, deterioration in the power factor due to reactive loads, voltage changes due to reactive power, flicker, unbalanced loads and harmonics. For new loads, an advanced planning be made to install the compensation equipment if needed, which can be predicted with reasonable accuracy applying simple rules.When acceptable limits are exceeded, it is uneconomical to connect the load to strong supply system, reactive power compensation and / or harmonic filtering equipments are well established as alternate solutions.

Several types of static compensators are currently available and suitable for most applications; however, care must be taken concerning the type of compensator, its proper design and cost.

Static compensator may also be employed for load balancing in cases where, in addition to being asymmetrical, the load is rapidly variable. Harmonic filters, when properly integrated with a supply system, provide a safe and effective solution the problem of excessive harmonic distortion. Since an harmonic filter inherently generates vars, it can usually be designed additionally to meet power factor correction requirement.

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Application of Artificial Intelligence Tools on Manufacturing

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ABSTRACT

Manufacturing systems in industries has dramatically changed as a result of advanced manufacturing technologies employed in today's factory. Factories are now trying to attend and maintain a world-class status through automation that is possible by sophisticated computer programs. The development of CAD/CAM system is evolving towards the phase of intelligent manufacturing system. A tremendous amount of manufacturing knowledge is needed in an intelligent manufacturing system. Artificial intelligence techniques are designed for capturing, representing, organizing, and utilizing knowledge by computers, and hence play an important role in intelligent manufacturing. Artificial intelligence has provided several techniques with applications in manufacturing like; expert systems, artificial neural networks, genetic algorithms and fuzzy logic. The potential power of AI is very great and it is believed that with the exploitation of AI methods, it will only possible to build well conceived and intelligent computer integrated manufacturing systems. In this paper the meaning of artificial intelligence and some of the most effective artificial intelligence tools are introduced. The applications of artificial intelligence tools in design and manufacturing are also discussed with some examples.

Keywords: CAD/CAM, Expert System, Genetic Algorithm, Fuzzy Logic, Neural Network.

1. INTRODUCTION

Artificial Intelligence (AI) emerged as a computer science discipline in the mid- 1950s. AI is concerned with systems that exhibit the characteristics usually associated with intelligence in human behaviaur, such as learning, reasoning, problem solving, understanding language, and so on. The main goal of AI is to simulate human behaviour on the computer.

The applications of AI in manufacturing, in particular, play a leading role in the technology development of intelligent manufacturing systems. The system belonging to this phase may be characterized by their ability to solve problems without either a detailed, explicit algorithm available for each solution procedure, or all the facts, mathemat ical relationship and models available in perfect arrangement and complete form for a deterministic and unique answer to be found. The manufacturing applications of AI span a wide spectrum including manufacturing system design, process planning, and process monitoring control, product quality control, and equipment fault diagnosis. The aim of this paper is to present the state of the art and highlight the recent advances on the AI applications in manufacturing.

2. EXPERT SYSTEMS

An Expert Systems (ESs) also called a knowledge-based system is an intelligent computer program that uses knowledge and reasoning techniques to solve problems that are difficult enough requiring significant human expertise for their solution [1]. An expert system may emulate the external behaviour of an expert, or it may attempt to closely model the internal mental processes of the expert as well. Ess has the ability to justify or explain the rationale behind a specific problem solution. ESs are particularly useful for problems based on a limited knowledge domain. Like conventional programs, ESs usually performs relatively well-defined tasks. Unlike conventional programs, expert systems can explain their actions, justify their conclusions, and provide end users with details of the knowledge they contain. An Ess system generally consists of the components as shown in the figure 1.

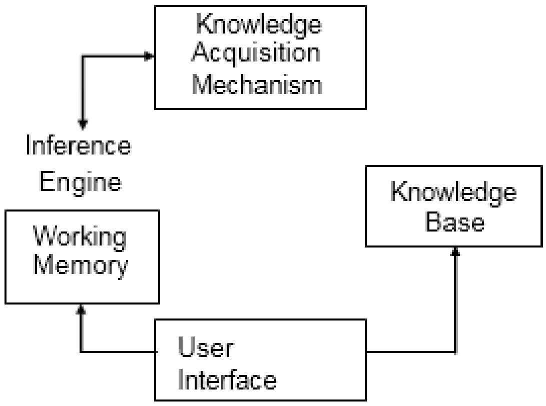


Figure 1: Structure of an Expert System

The user interface is designed to provide a convenient means of two-way communication between the user and the inference engine. An end user who tries to find a solution to a problem can describe the context of his problem to the system by means of the user interface. The knowledge base is a file that contains the facts and heuristic that makes up an expert's knowledge. A knowledge base is different from a typical data file or database. In a database, knowledge about the problem domain may be implicitly represented by the structure of the database. The actual contents of a database are the facts, data or information rather than knowledge. On the other hand, in the ESs, knowledge about the problem is explicitly represented in the knowledge base. A knowledge acquisition mechanism is used to acquire human expertise and transform into the knowledge base. This module processes the data entered by the expert and transforms it into a data presentation understood by the system. The inference engine is the knowledge processor that looks at the problem description and tries to find a solution with the help of factual and meta-knowledge. It can be considered as a program that applies domain knowledge to known facts to draw conclusions. The explainer is used to find out how a solution was obtained from an expert system and which individual steps were taken. The user can communicate with the explainer to obtain a report about the operation of the expert system.

Ess offers an environment for incorporating the capabilities of humans and the power of computers. Some of the advantages of ESs are summarised as follows:

- ESs can accommodate new expertise whenever new knowledge is identified
- ESs are able to explain their recommendations
- ESs can apply heuristics to reduce the complexity of search
- Ess reduce the company's reliance on human experts by capturing expert knowledge and store the knowledge in computers Some of their disadvantages are listed below:
- Debugging and maintenance of a large (or complex) ES is very difficult
- The human expert must be available in order to build an ES
- The human expert must be able to articulate the rules that define the solution and not lapse into vagueness or incoherence
- The development of an ES can be a lengthy-process depending on the size of the problem domain
- An ESs performance drops off sharply if the problem deviates even slightly from the expected problem domain
- In a large and complex ES, the execution time of the system can also be a problem

There are numerous ESs being developed for almost any manufacturing activity [2]. ES is widely used in design, process planning, scheduling, material handling, quality control, machine diagnosis, machine layout and other operations.

3. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Network (ANN) technology imitates the brain's own problem solving process. Neural networks are systems composed of many simple processing elements operating in parallel and whose functions are determined primarily by the pattern of connectivity.

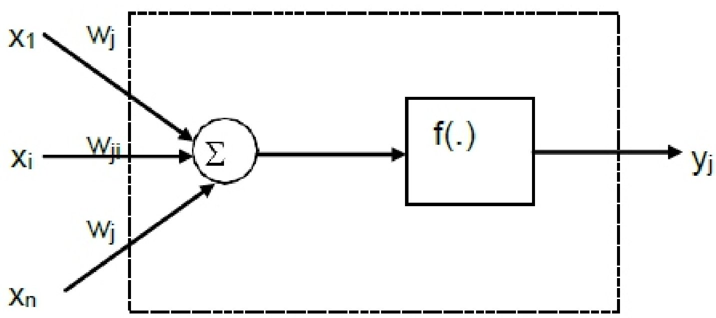
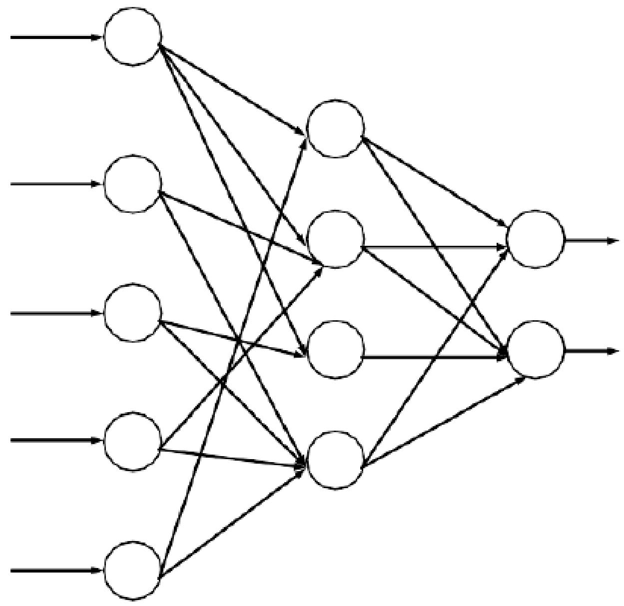


Figure 2: Model of a Neuron

Figure 2 illustrates a typical model of a neuron. Output signal yj is a function f of the sum of weighted input signals xi. The activation function f can be a linear, simple threshold, sigmoidal, hyperbolic tangent or radial basis function. Instead of being deterministic, f can be a probabilistic function, in which case yj will be a binary quantity, for example, +1 or –1. The net input to such a stochastic neuron; that is, the sum of weighted input signals xi, will then give the probability of yj being +1 or -1 A neural network may be considered as a black box that can accept a series of input data and produce from these one or more outputs [3]. A neural network takes an input numeric pattern and produces an output numeric pattern. A typical ANN structure is illustrated in Figure 3.



Input Layer Hidden Layer Output Layer

Figure 3: A Typical ANN Structure

As depicted in Figure 3, the basic components of an ANN are neurones. A group of neurones is called a slab. Neurones are also grouped into layers by their connection to the outside world. If a neurone receives data from outside world, it is considered to be in the input layer. If a neurone contains network's predictions or classifications, it is in the output layer. Neurones between the input and output layers are in the hidden layer(s). A layer may contain one ore more slabs of neurones.

Most of the ANN models can be trained adaptively. Adaptive neural networks can be trained using two types of training procedures, supervised training and unsupervised training. In supervised learning, the training process involves providing the network with known sets of input and the corresponding outputs. A network is said to have learned if it can produce the desired outputs when a sequence of inputs are provided. In unsupervised learning, the learning process is based on clustering. Unsupervised networks can classify a set of training patterns into a specified number of categories without being shown in advance how to categorise.

A potential important advantage of neural networks is their high degree of error resistivity. The advantages of ANNs over conventional computing are listed below:

- ANNs have the ability to generalise. From past experience, they can give a solution to a new problem.
- ANNs do not need an expert to represent knowledge and does not require much programming knowledge
- ANNs have a simpler structure, since only the input and the output of the system are simulated
- ANNs have a good ability to tolerate faults and missing data, making it useful where all the rules and data are not known
- ANNs are self-organising and can learn. These characteristics make it suitable for those tasks that were originally done by humans
- The massive number of processing elements (neurones) makes neuro-computing faster than conventional computing
- When fully developed, neural hardware is expected to be 20 to 50 times smaller in size than conventional computers

However some of the scientific economic expectations on ANNs are unreasonab le. This is because ANNs have the following drawbacks:

- The configuration of an ANN is usually time consuming, as one needs to use a trial- and-error method to find the proper neural network architecture for a given problem
- The knowledge representation of an ANN is imprecise and not easily understood
- ANNs cannot explain its results explicitly, which implies that the user interface of a neural network may not be as friendly or productive as that of an expert system
- The current learning algorithms for ANNs are not efficient enough and cannot guarantee network convergence
- How to derive some type of optimal training set for a neural network application still remains a question

The application area of neural networks in CAD/CAM is quite broad. It covers nearly all of the fields spreading from the design phase through simulation, control, monitoring and quality assurance to the maintenance.

4. FUZZY LOGIC

Fuzzy Logic (FL) is another tool of AI that is gaining popularity in recent years. It is based on the observation that people make decisions based on imprecise and non-numerical information; fuzzy models or sets are mathematical means of representing vagueness and imprecise information, hence the term fuzzy. These models have the capability of recognising, representing, manipulating, interpreting, and utilising data and information that are vague and lack certainty. Linguistic examples are: a few, almost all, more or less, very important, good, poor, appropriate, acceptable, etc. [4]. Anything that was built using conventional techniques can be built with the FL. However, in a number of cases, conventional solutions are simpler, faster, and more efficient. The key to successful use of FL is clever combination with conventional techniques [5].

Fuzzy logic has been mainly suggested to handle fuzzy concepts, inexact information, and approximate reasoning in expert systems. In FL, the knowledge representation is explicit, the verification is easy and optimisation of the system performance is possible. On the other hand, FL has no training ability. Everything should be defined explicitly to the system. Trainability is the most important function of ANNs. Therefore, if the explicit knowledge representation capability of fuzzy logic is combined with the learning power of ANNs, a more powerful technology can be obtained. Such systems are called NeuroFuzzy Systems.

Matsuhista has built a fuzzy washing machine that combines smart sensors with fuzzy logic. The sensors detect the colour and kind of clothes present and the quantity of grit, and a fuzzy microprocessor selects the most appropriate combination from 600 available combinations of water temperature, detergent amount and, wash and spin cycle times. Zhang and Huang have recently developed a fuzzy approach for process plan selection [6]. In their approach, each process plan is evaluated and its contribution to shop floor performance is calculated using the fuzzy set theory.

5. GENETIC ALGORITHMS

Genetic Algorithms (GAs) are robust search algorithms based on the mechanics of natural selection and genetics. They are used to abstract and explain the adaptive processes of natural systems to design artificial systems software that retains the important mechanisms of natural systems. GAs work with a coding of the parameter set and search from a rich population of strings. They use only an objective function (fitness) information, not derivatives or any other auxiliary knowledge. GAs use probabilistic transition rules, not deterministic rules. The flowchart of simple GA is given in figure 4. There are basically four genetic operators: selection, crossover, mutation, and inversion [7]. There are also other types of operators that yield good results like partially matched crossover (PMX). The choice of operators depends on the problem and representation scheme employed. For instance, operators designed for binary strings cannot be directly used on strings coded with integers or real numbers.

The aim of selection procedure is to reproduce more of individuals whose fitness values are higher than those whose fitness values are low. The selection procedure has a significant influence on driving the search toward a promising area and finding good solution in a short time. However, the diversity of the population must be maintained to avoid premature convergence and to reach the global optimal solution.

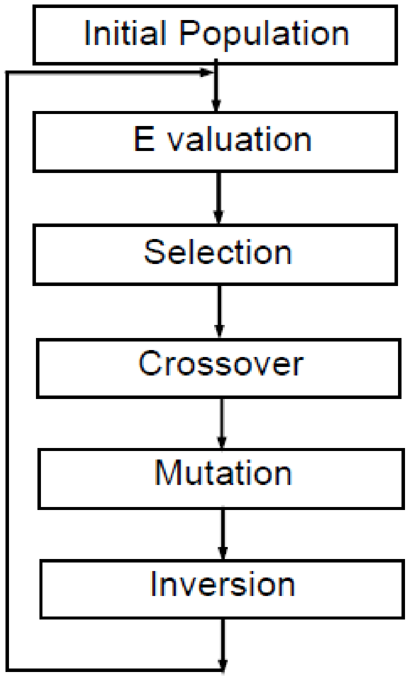


Figure 4: Flowchart of a basic GA

An example of one point crossover, mutation, and inversion is shown in figure 5. Important control parameters of a simple GA include the population size, crossover rate, mutation rate, and inversion rate. Several researchers have studied the effect of these parameters on the performance of a GA [8-9].

Parent 1 : 1 0 0 | 0 1 0 0 1 1 1 1 0

Parent 2 : 0 0 1 | 0 1 1 0 0 0 1 1 0

New string 1 : 1 0 0 | 0 1 1 0 0 0 1 1 0

New string 2 : 0 0 1 | 0 1 0 0 1 1 1 1 0

(a) Crossover

Old string : 1 1 0 0 | 0| 1 0 1 1 1 0 1

New string : 1 1 0 0 | 1| 1 0 1 1 1 0 1

(b) Mutation

Old string : 1 0 | 1 1 0 0 | 1 1 1 0 1

New string : 1 0 | 0 0 1 1 | 1 1 1 0 1

(c) Inversion

Figure 5: Crossover, mutation, and inversion of binary string segment

A large population size means the simultaneous handling of many solutions and increases the computation time per iteration; however, the probability of convergence to a global optimal solution is higher than with a small population size. The crossover rate determines the frequency of the crossover operation. A low crossover frequency decreases the speed of convergence to such areas. If the frequency is too high, it can lead to saturation around one solution. The mutation operation is controlled by the mutation rate. A high mutation rate introduces high diversity in the population and might cause instability. On the other hand, it is usually very difficult for GA to find a global optimal solution with too low mutation rate.

GAs has found application applications in engineering problems involving complex combinatorial or multiparameter optimisation. GA is widely used for scheduling the operations of a job shop, for designing the knowledge base of fuzzy logic controllers and many other problems.

6. CURRENT STATUS OF AI TECHNOLOGY AND ITS FUTURE

There have been numerous applications of AI for CAD/CAM for almost all design and manufacturing activities; from feature recognition to optimisation. ES is widely used in design, process planning, scheduling, material handling, quality control, machine diagnosis, machine layout and other operations. ANNs can be used for; quality control, pattern recognition, resource allocation, optimisation, scheduling, maintenance and repairing, process control and planning, database management, simulation, and robotics control. FL has been preferred for those problems in which there are conflicting process parameters, while GAs have been generally used for the optimisation issues such as optimisation of cutting parameters and operation sequences.

The impact of Artificial Intelligence (AI) tools (like Expert Systems, Neural Networks, Genetic Algorithms, and Fuzzy Logic) on the planning of manufacturing processes has been proven by recent research projects and actual implementations. There are numerous packages being developed for almost any manufacturing activity. A conservative estimate is that only 5% of all research endeavours have found their place in the factory. This may be a very discouraging reality; but there are following reasons for this problem:

- The tools for building intelligent systems are not sufficiently developed and are difficult to apply.
- The methods for acquiring knowledge from experts to develop expert systems are not very well understood.
- There are too few qualified people available who really know how to apply AI tools. Using or developing right tools, methods and environments can solve these problems.

However, the potential and power of AI is very great and it is believed that with the exploitation of AI methods it will only be possible to build well conceived and intelligent CAD/CAM systems in which many routine jobs (which may become very repetitive and boring, after the skill has been acquired) are taken out of the experienced manager so that his creativity can be devoted to solving more complex problems in factory [10].

The development of powerful, intelligent, optimised and flexible CAD/CAPP/CAM systems in IMS concept will only be possible with the extensive and true use of Artificial Intelligence. AI tools like ESs, ANNs, GAs, FL, SA offer promising solutions in the areas of product definition, layout design, process p lanning, optimisation and so on. The next generation of intelligent manufacturing systems will hopefully integrate the computational paradigms of expert or knowledge based systems and artificial neural networks, as well as other promising methodologies like fuzzy logic and genetic algorithms. Different techniques related to AI must be used in amalgamation to eliminate and to take the disadvantages and advantages of individual methodologies, respectively. Thus, it will be possible to realise the goals of lMS.

7. CONCLUSION

Over the past 40 years, AI has produced a number of powerful tools. This paper has reviewed four of those tools, namely, expert system, artificial neural networks, fuzzy logic, and genetic algorithms. Applications of the tool in CAD/CAM have become more widespread due to the power and affordability of present-day computers. It is anticipated that many new applications will emerge and that, for demanding tasks, greater use will be made of hybrid tools combining the strengths of two or more of the tools. Other developments in AI that will have an impact in engineering include data mining, or the extraction of information and knowledge from large databases, and multi-agent systems, or distributed self-organising systems employing entities that function autonomously in an unpredictable environment concurrently with other entities and processes. The appropriate use of these new AI tools and the tools presented in this paper will contribute to the creation of more competitive engineering systems.

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Comparing Manual and Automatic Normalization Techniques for Relational Database

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ABSTRACT

Normalization is a process of analyzing the given relation schemas based on their Functional dependencies and primary keys to achieve the desirable properties of minimizing redundancy. It aims at creating a set of relational tables with minimum data redundancy that preserve consistency and facilitate correct insertion, deletion, and modification. A normalized database does not show various insertions, deletion and modification anomalies due to future updates. This paper presents a comparison study of manual and automatic normalization technique using sequential as well as parallel algorithm. It is very much time consuming to employ an automated technique to do this data analysis, as opposed to doing it manually. At the same time, the process is tested to be reliable and correct. It produces the dependency matrix and the directed graph matrix, first. It then proceeds with generating the 2NF, 3NF, and BCNF normal forms. All tables are also generated as the procedure proceeds.

Keywords: Automatic Normalization, Manual Normalization, Relational Database, Functional Dependency, and Primary Key.

1. INTRODUCTION

Database normalization is the process of transforming data into well- formed or natural groupings such that one fact is stored in one place [1]. Normalization generally simplifies the relations and reduces the danger of anomalies [2] that may otherwise occur during manipulation of the relations in a relational database. Moreover, normalized data is stable and, therefore, provides a good foundation for any future growth. Thus, the normalization procedure provides database designers with a formal framework for analyzing relation schemas based on their keys and on the functional dependencies among their attributes [3]. It also provides a series of normal form tests that can be carried out on individual relation schemas so that the relational database can be normalized to any desired degree. E.F.Codd first formalized the process of normalization. It takes a relation schema through a series of tests to certify whether it satisfies a certain normal form. The normal form of a relation refers to the highest normal form condition that it meets, and hence indicates the degree to which it has been normalized. Three normal forms called first (1NF), second (2NF), and third (3NF) normal forms were initially proposed. An amendment was later added to the third normal form by R. Boyce and E.F. Codd called Boyce–Codd Normal Form (BCNF). The trend of defining other normal forms continued up to eighth normal form. In practice, however, databases are normalized up to and including BCNF. A relation is in first normal form if every field contains only atomic values, that is, no lists or sets, in the sense that it should not be able to be broken into more than one singleton value. Each normal form except the 1NF is defined on top of the previous normal form. That is, a table is said to be in 2NF if and only if it is in 1NF and it satisfies further conditions. Except for the 1NF, the other normal forms are based on Functional Dependencies (FD) among the attributes of a relation. A functional dependency (FD) is a constraint between two sets of attributes in a relation from a database [4]. Given a relation R, a set of attributes X in R is said to functionally determine another attribute Y, also in R, (written $X \rightarrow Y$) if, and only if, each X value is associated with precisely one Y value. X is said to be the determinant set and Y the dependent set. Given that A, B, and C are sets of attributes in a relation R one can derive several properties of functional dependencies. Among the most important ones are Armstrong's axioms. These axioms are used in database normalization:

Axiom of Reflexivity: If B is a subset of A, then A -> B If A -> C, then AB -> CB

Axiom of Transitivity: If A -> B and B -> C, then A -> C

Axiom of decomposition, or projection: If A -> BC, then A -> B and A -> C

Axiom of pseudotransitivity: If A->B, CB-> D, then AC -> D

Normalization is a major task in the design of relational databases [4]. Mechanism of the normalization process saves tremendous amount of time and money.

2. TRADITIONAL AND AUTOMATIC NORMALIZATION TECHNIQUE

2.1 Traditional Approach

As already mentioned, except the 1st normal form rest all normal forms depend upon FD'S. In the traditional method of normalizatio n we follow the abstract definitions of these normal forms and apply them to concrete problems [5]. To demonstrate this point, consider the following example, in which information concerning Suppliers, parts, and shipments is stored in a single relation:
First (S#, Status, City, P#, Quantity)

Here we assume that the relation is in 1st normal form. Now according to the definition of 2nd normal form, every non-prime attribute should be fully functional dependent on the primary key. So first to identify which attribute or combination of attribute makes primary key we need to run the following algorithm [6]:

A universal relation R and a set of FD'S F on attributes of R .

To find key K

1. Set K: =R
2. For each attribute A in K

{Compute (K-A)+ w.r.t F;

IF (K-A)+ contains all attributes in R, then set K: =K- {A}};

We found out that the combination of (S#, P#) makes the primary key of this relation. Our given relation violates the 2NF condition, as city and status are partially dependent on primary key, which will lead to redundancy as well as anomalies. So according to the rule we remove the partially dependent attributes from our original relation by decomposing it into two relations as follows:

First1 (S#, P#, Quantity) First2 (S#, City, Status)

The above two relations are in 2NF.Now for a relation to be in 3NF,every nonprime attribute should be non-transitively dependent on the primary key [7]. So according to this definition the danger of running into the various anomalies in First2 still exists, however. For example, if a tuple that gives a specific city has a specific status that needs to be inserted, it cannot be inserted until some supplier actually moves to that city (insertion anomaly). If only one supplier is in a city and that supplier is deleted, then the info rmation about the status of that city is lost (deletion anomaly). Finally, if the status for a specific city needs to be changed, every tuple for that city must be located and changed (updating anomaly). The reason for the danger of anomalies in First2 is the transitive dependency of status on S# via city. Each S# value determines a CITY value, and that CITY value determines the STATUS value. The solution to the problems is to decompose the First2 relation into two relations:

First21 (S#, City) First22 (City, Status)

The above two relations are in 3NF. Moreover the decomposition is loss less and dependency preserving. Unfortunately, this traditional approach was difficult for many IS/IT students to grasp and/or apply the definitions. They cannot differentiate between the three normal forms and are confused about the relationships between FDs and normal forms. So Hsiang-Jui Kung and Han Reichgelt proposed an alternate method.

2.2 Automatic normalization approach using sequential algorithm

Like this many other approaches were being introduced. But despite normalization importance, very few algorithms have been developed to be used in the design of commercial Automatic normalization tools. Mathematical normalization algorithm is implemented in [8]. In [9] a set of stereotypes and tagged values are used to extend the UML meta- mode. A graph rewrite rule is then obtained to transfer the data model from one normal form to a higher normal form. Later on Amir Hassan Bahmani came up with the automatic database normalization technique, which use dependency graph diagrams to represent functional dependencies of a database [10]. This approach use three structures, Dependency Graph (DG), Dependency Matrix (DM), and Directed Graph Matrix (DG), to represent and manipulate dependencies amongst attributes of a relation. After generating the DG matrix we turn our attention towards finding Determinant key transitive dependencies matrix that will show all transitive dependencies between determinant keys. The proposed 2NF and 3NF normalization process makes use of both dependency and determinant key transitive dependencies. To produce the 2NF form, we should find all partial dependencies; it is assumed that the table is already in 1NF form. In order to transform the relations into 3NF, each DM is scanned row by row starting from the first row. If a determinant key is encountered whose dependency is neither partial (from Figure 16) nor it is wholly dependent on part of the primary key a separate table has to be formed. Of course, if a table is previously formed a duplicate is not generated. This new table will include the determinant key and all other attributes, which are transitively, depend on this key. For a relation with only one candidate key, 3NF and BCNF are equivalent. Let us take the previous example and solve it using the above- mentioned technique:

First (S#, Status, City, P#, Quantity) S#, P# -> Quantity

City -> Status

S# -> City, Status

The graphical representation of the dependencies:

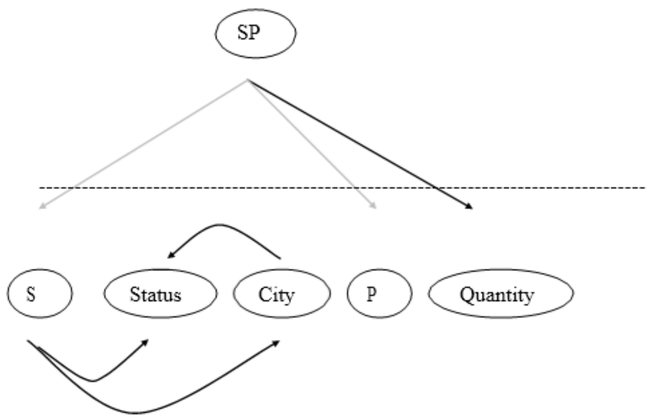

Fig1: Graphical representation of dependencies

If we are able to obtain all dependencies between determinant keys we can produce all dependencies between all attributes of a rela tion. These dependencies are represented by using a Dependency Matrix (DM). Using path finding algorithms and Armstrong's transitivity rule new dependencies are discovered from the existing dependency set.

Dependency Matrix:

From a dependency graph, the corresponding Dependency Matrix (DM) is generated as follows:

i. Define matrix DM [n] [m], where

n = number of Determinant Keys.

m = number of Simple Keys.

	S	P	CITY	STATUS	QUANTITY
SP	2	2	0	0	1
CITY	0	0	2	1	0
S	2	0	1	1	0

Directed Graph Matrix:

The Directed Graph (DG) matrix for determinant keys is used to represent all possible direct dependencies between determinant keys. The DG is an n×n matrix where n is the number of determinant keys. After running the algorithm for producing the DG graph, we get the following DG matrix:

	SP	CITY	S
SP	1	-1	1
CITY	-1	1	-1
S	-1	1	1

After generating the DG matrix we turn our attention towards finding all possible paths between all pairs. This matrix will show all transitive dependencies between determinant keys. There is many such path finding algorithms like Prim, Kruskal, and Warshal algorithms. If there is a path from node x to node y it means y transitively depends on x.

	SP	CITY	S
SP	1	-1	1
CITY	-1	1	-1
S	-1	1	1

Fig 2: Determinant key transitive dependencies

DM of Figure 2 is updated as follows to reflect all dependencies including those that are obtained by Dependency-closure procedure.

	S	P	CITY	STATUS	QUANTITY
SP	2	2	S	S	1
CITY	0	0	2	1	0
S	2	0	1	CITY	0

Fig 3: Dependency closure matrix

It is now the time to replace direct dependencies, which might have disappeared by applying transitive dependencies. However, the FindOne algorithm does not discover any fade away dependency. Therefore, Figure 3 shows the optimal dependency set. Entries with value 1 are identify components of this set. We are now in a position to obtain candidate keys. Acandidate key is a set of attributes to which all other attributes depend on. From the final DM we notice that SP has this property. This proposed 2NF and 3NF Normalization process makes use of both dependency and determinant key transitive dependencies. To proceed with the 2NF, it is assumed that the table is already in 1NF form. The resulting 1NF relation is: SP_Relation: {SP, City, Status, Quantity}.

The goal is to discover all partial dependencies. To produce the 2NF form, we should find all partial dependencies. To do this, the DM is scanned row by row (ignoring the primary key row), starting from the first determinant key of the row being scanned are equal to 2 and the values of the corresponding columns of the candidate key are equal to 2, then a partial dependency is found. In Figure 3, the dependency of City to SP is partial.

row. Therefore, we have to create a new table. In Figure 4, the DM matrix is partitioned into two new DMs corresponding to new tables.

	S	P	QUANTITY
SP	2	2	1

(a) SP_relation: {SP, Quantity}

	S	CITY	STATUS
S	2	1	CITY
CITY	0	2	1

(b) S_relation: {S, City, Status}

Figure 4: Database normalized up to 2NF

In order to transform the relations into 3NF, each DM is scanned row by row starting from the first row. If a determinant key is encountered whose dependency is neither partial (from Figure 4) nor it is wholly dependent on part of the primary key a separate table has to be formed. Of course, if a table is previously formed a duplicate is not generated. This new table will include the determinant key and all other attributes, which are transitively, depend on this key.

	S	P	QUANTITY
SP	2	2	1

(a)

	S	CITY
S	2	1

(b)

	CITY	STATUS
CITY	2	1

(a)

Figure 5 : Database Normalized up to 3NF

For a relation with only one candidate key, 3NF and BCNF are equivalent.

2.3 Automatic normalization approach using parallel algorithm

While existing sequential algorithms are usually much time consuming, especially the process of transforming relations into 3NF, so the proposed parallel algorithms for automatic database normalization was given. The proposed algorithms have been examined with MPI and its implementation results on EDM showed that parallel approach reduces the time, efficiently [11]. Exploiting p processors has reduced the time of Automatic Database

Normalization to $\frac{n^2.m}{p} + c$ in which c is the communication overhead between the processors, m is the number of simple keys, and n is the number of determinant keys.

CONCLUSION

As we saw in traditional approach students need to remember the abstract definition of normal forms, moreover in some places canonical cover is supposed to be found out. This approach also requires finding out the primary key by applying algorithm, which again is a difficult job for students. Later automatic approach using both sequential and parallel algorithm were given. The process is based on the generation of dependency matrix, directed graph matrix, and determinant key transitive dependency matrix. The benefit of this approach over traditional approach is Primary Key is automatically identified for every final table that is generated. It is very much time consuming to employ an automated technique to do this data analysis, as opposed to doing it manually. At the same time, the sequential process is tested to be reliable and correct. The MPI implementation of (parallel algorithm for automatic database normalization) results on a cluster with eight processors indicates a considerable reduction in time of the automatic database normalization process. All these algorithms are very efficient. However, i will compare these algorithms with other similar algorithms, in the future.

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