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Two Stages Scheduling of Steel Making using Earliest Deadline First Algorithm

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Abstract: Steel making is a process of converting hot metal into liquid steel by removing impurities by oxidation process. In this process Oxygen is blown into hot metal to oxidize impurities like carbon, Manganese, Sulhpur, Phosphorous and it will form into a slag. After tapping the steel into the ladle Ferro Alloys are added to achieve the target grade of the steel. The liquid steel is sent to Argon Rinsing station for homogenizing the steel and killing the steel to remove dissolved oxygen. In the continuous casting process the homogenized steel is allowed to flow into tundish and from there into bottom less mould. The semi cooled piece of bloom is continuously drawn out of mould and cut into required length pieces. Under one tundish several moulds may be available as per design.

Scheduling a Steel making process is a very complicated and it involves lot of equipment and dynamism in nature. Lot of research is ongoing to schedule the steel making process and many attempts have been made using different kinds of algorithms.

In this paper the authors have attempted to schedule steel making process at LD and ARS Processes. Different grades are produced in LD Converter based on the Hot Metal supply. Hot metal supply comes from the blast furnace in the form of Jobs. These jobs allocated to the LD Converters using Earliest Dead line first (EDF) scheduling algorithm. The output of LD converters are further processed in Argon Rinsing Stations(ARS) and send to continuous casting machines (CCM) to cast into Blooms. The Heats/Jobs arrived ARS are scheduled based on EDF Scheduling. The EDF algorithm used at LD and ARS have shown better performance metrics when compared with other conventional models metrics.

In this paper, the authors have designed and developed a scheduling model based on Earliest Dead Line First. The authors have evaluated performance metrics of the model like Turnaround time, Average waiting time and dead line deviation.

These results indicated that the scheduling model has shown a significant improvement of EDF on the job scheduling when compared with conventional methods like First Cum First scheduling (FCFS) , Shortest Job First (SJF).

I. INTRODUCTION

Steel making is a process of converting Hot Metal into liquid steel by blowing oxygen in a converter having a capacity about 150 T. The impurities will get oxidized and called as slag floating on the liquid steel having temperature 1700 C. The alloying additions are added into ladle after tapping depending on the grade of steel to be produced. The blowing time depends on the silicon in the hot metal and grade to be produced. Steel is tapped into ladles from converter and sent to Argon Rinsing Station (ARS). In the Argon Rinsing Station (ARS) the steel is rinsed with Argon to homogenize the steel and drive out dissolved oxygen. Killing agents are added to deoxidize the steel. After rinsing the steel is sent to Continuous casting machines for casting.

In the continuous casting the liquid steel in the ladle is kept on turret stand and poured into tundish which is having nozzles at the bottom. These nozzles are opened to bottom-less moulds and the partially the continuous casting solidified metal is drawn continuously from the bottom and cut to length at the gas cutting machine. Different grades of steel require different super heat based on the TTT curve and accordingly time of casting varies with the grade being cast. The speed of casting depends on the super heat and grade.

The total steel making process involves the following important steps.

1. Blowing of Hot metal in LD converter about 150 tons of steel is produced
2. In the ARS Ferro Alloys are added to adjust the alloying elements to reach the aim Grade of the steel
3. Rinsing of the Steel with Argon to homogenize the steel and to kill the steel to remove the oxygen content. Sometimes temperature of the steel is raised to meet the requirement of casting. Generally

about 50^{o}C super heat is maintained in the steel above liquidous temperature based on the carbon equivalent

4. In the Continuous Casting Machine Liquid steel is cast into Blooms/Slabs/Billets by pouring steel into bottom less moulds and drawing the semi solidified blooms out and cut into required length in a gas cutting machine.

The scheduling of steelmaking continuous-casting (SCC) processes is of major importance in iron and steel operations, since it is often a bottleneck in iron and steel production. Optimal scheduling of SCC processes can increase profit, minimize production cost, reduce material and energy consumption, and improve customer satisfaction. All these parameters performance metrics mostly depends on the type of scheduling of heats in LD Converters and ARS stations Scheduling of SCC involves sequencing of jobs on LD Converter , Argon Rinsing and Continuous Casting in a non-preemptive so that total elapsed time and average waiting time are minimum.The scheduling of Steel Making and Continuous Casting involves sequencing of heats based on the grade to be made and timings in each unit to be spent which depends on the service rate at LD Converters and ARS.

The steel that is produced in one treatment time is called a Heat. The number of heats of different steel grades is produced in steel melting shop in a day and the different heats to be produced is known wellin advance. In the Steel Melting shop, these heats are being planned randomly without any logic and more or lesson first cum first basis. The heats one by one gets processed in LD Converter and sent to argon rinsing station for further processing. In this research, authors have focused on mainly different schedulingalgorithms of the heats so that effective utilization of the machines increased and waiting time is reduced.

As The authors tried to explore other different models for the heats scheduling in steel making to improve the productivity, effective utilization of machines and cost of production. The authors have tried Shortest Job First (SJF), Earliest Deadline First (EDF) for the two machines i.e LD converters and Argon Rinsing Stations(ARS) and compared with FCFS and SJF scheduling. The metrics like Turnaround time, Average waiting time and dead line deviation which are used to evaluate performance of the machines are comparedfor the different models for effectiveness of each model over the other. For data validation and verification number of heats/Jobs data taken from the Steel Plant Production data.

These results indicated that the EDF scheduling model has shown a significant improvement of over First Come First Scheduling (FCFS) , Short Test Job First (SJF). This indicated that in the steel making the model EDF has given effective utilization of LD Converters and Argon rinsing stations and improvement of productivity over presently being used FCFS modeling.

II. RELATED WORK

Liro Harjunkoski, Guido Sand (2000) have presented MILP-models for melt shop scheduling optimization that can be flexibly adapted to different plant structures. Moreover, the flexibility allows for modeling individual characteristics of parallel equipment, particular processing and changeover times, scarce resources and maintenance requests. Vikas Kumar and etal (2000),formulated the scheduling problem in steel making as a linear integer program to determine the scheduling sequence for differentcharges. Bids are then obtained for sequencing the charges and a heuristicapproach is used to evaluate the bids.The proposed algorithm has beenverified by a case study.

X.F.Li etal (2001), presented a new modeling method that is called Extended Timed Synchronized Colored PN (ETSCPN) to set up the dynamic model of the whole system. Further a hierarchic algorithm was presented to solve the dynamic scheduling of the model. The simulation result demonstrated that the algorithm is efficient and fit for the dynamic scheduling of a class of multiple stages and multiple machines and FIFO system. Dario Pacciarelli etal(2004), formulated production planning based on the alternative graph which details the constraints relevant for the scheduling problem. The problem of scheduling is solved by beam search procedure and compared the results with a lower bound of the optimal solutions and with actual performance obtained in the plant.

PA Guegler and FJ Vasko et al(2007) presentedan efficient domain-specific heuristic is combined with metaheuristic approaches in a prototype scheduling model. Specifically, given preliminary schedules for the continuous casters, the model determines the allocation, sequencing, and scheduling of batches of steel at the basic oxygen steelmaking furnaces, the degassing facilities, and the ladle treatment stations. It also makes the appropriate schedule modifications at the continuous casters. Computational results are presented.Kebin Lu etal (2008), presented a hybrid heuristic and optimization algorithms for the integrated scheduling problem of steel-making and continuous casting. The scheduling system had been embedded into the whole MES of a big iron and steel group in China. They have achieved the satisfactory results.

Hubert Missbauer etal (2009), presented the models, algorithms and implementation results of a computerized scheduling system for the steelmaking-continuous casting process of a steel plant in Austria. Extensive numerical tests with real-life data and more than two years of experience with the implementation demonstrate that the system produces reasonable schedules and is accepted by the planners. Arezoo Atighehchian et al. (2000), presented steel-making continuous casting (SCC) scheduling problem (SCCSP). They have developed algorithm, named HANO, is based on a combination of ant colony optimization (ACO) and non-linear optimization methods. The efficiency of HANO is compared with heuristic and genetic algorithms as a real case used at Mobarakeh Steel Company (MSC), the biggest steel factory in the Middle East. Numerical results reveal the higher efficiency of the developed approach compared with the heuristic one used at MSC.

H. B. Wang and etal (2010) presented a genetic algorithm model for production scheduling as JSSP with fuzzy processing and delivery time.The test results show that the improved genetic algorithm can find better solution. Xiu-ying wang etal (2010) , presented a model for scheduling steel-making and continuous casting combining the mathematical programming, fuzzy logic, expert system based techniques. The results demonstrated that the proposed scheduling strategy to some extent satisfy the requirement of practical production.

IESLi,Xin Xiao etal (2012), developed a novel unit-specific event-based continuous-time mixed-integer linear optimization (MILP) model for this problem and incorporate several realistic operational features. Four large-scale industrial problems are used to illustrate the efficiency and effectiveness of the proposed formulation and rolling horizon approach. The computational results show that the extended rolling horizon approach successfully solves the large-scale case studies and results in the same or better integer solution than that obtained from directly solving the entire scheduling model.

Worapradya.K, Thanakikasem P etal [2014], formulateda new optimization model that more closely represents real-world situations, and a hierarchical genetic algorithm (HGA) tailored particularly for searching for an optimal Steel Making-Continuous Casting Schedule. The optimization model is developed by integrating two main planning phases of traditional scheduling: (1) planning cast sequence, and (2) scheduling of steel-making and timing of all jobs. A Worapradya, Purit Thanakijkasem etal. [2015], presented an artificial neural network (ANN) based model adopted with a challenge of designing an accurate model due to the model complexity from the discrete and nonlinear properties of the system performance. The experimental result shows that the proposed methodology is successful in designing a robust schedule that provides a lower production cost under an acceptable breakdown probability.

In the literature, very little work on Scheduling of Steel Making and Continuous Casting (SCC) reported. In the available literature researchers have focused on Artificial Intelligence and Nueral networks to solve the SCC scheduling problem. No author reported the research on SCC Scheduling using Deadline Concept. Deadline aware Scheduling concept is most important concept being used in all industrial scheduling activities. Hence authors have chosen EDF methodology for scheduling of heats to LD converters and ARS stations of steel making.

III. EARLIEST DEADLINE FIRST ALGORITHM

Steel production is an extremely complex process and determining coherentSchedules for the wide variety of production steps in a dynamic environment,where disturbances frequently occur, is a challenging task. In the steel productionprocess, the blast furnace continuously produces liquid iron, which is transformedinto liquid steel in the melt shop. The majority of the molten steel passes througha continuous caster to form large steel blooms, which are rolled into coils/angles/bars/rounds/structural in Wire rod Mill, LMMM, MMSM mills.The scheduling system of these processes has very different objectivesand constraints, and operates in an environment where there is a substantialquantity of real-time information concerning production failures and customerrequests. The steel making process, which includes steel making followedby continuous casting, is generally the main bottleneck in steel production.Therefore, comprehensive scheduling of this process is critical to improve thequality and productivity of the entire production system.In this research authors considered the output of Blast Furnace i.e Hot Metal as input to LD Converter and the output of LD Converters is the output to ARS Stations.

The scheduling of Steel Making and Continuous Casting involves sequencing of heats based on the grade to be made and timings in each unit to be spent. Deriving an optimized sequencing of the Heats/Jobs from converter to Caster will give more productivity and optimum machine utilization. The aim of the research is to derive an optimized scheduling based on the timings of blow, rinsing and casting which is depends on the many metallurgical constraints.

In this paper authors have consideredfor two machines of steel making namely LD Converter and Argon Rinsing Unit. In this research it is considered thatthere are ‘m’ number of converters parallely operating and processing heats and there are ‘n’ number of Argon Rinsing Units parallely processing heats. The model randomly determines a factor for each job/heat and finds out a *deadline time* for each job/heat. After deadlines are arrived for each heat / job the jobs are ordered based on the *deadline function* in ascending order is sequenced. The scheduling model considers for each 4 jobs/heats it sequences on one stream of LD converter (M1) and Argon rinsing station (M2). The concept of multiple machine scheduling is shown in Figure 1.

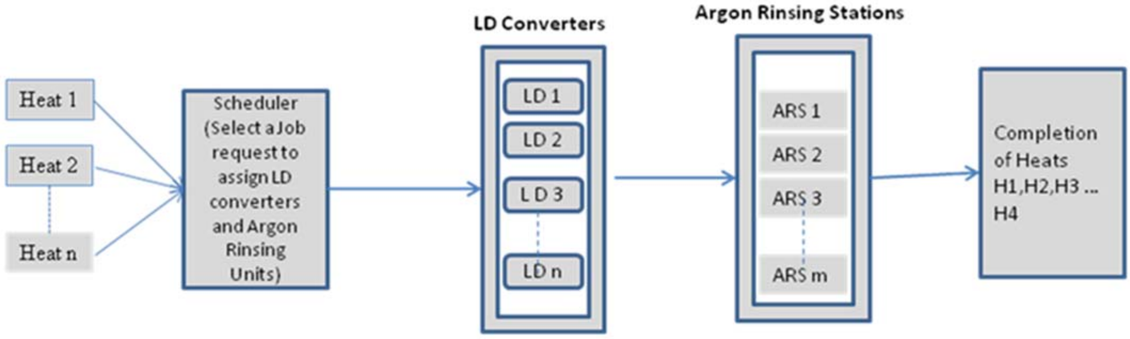

Fig. 1 Depiction of scheme of scheduling activity in LD Converters and Argon Rinsing Stations in a Steel Melting Shop

Deadline time for each job/heat is calculated based on the total time it takes to process each heat in the LD converter(M1) and Argon Rinsing Station (M2) and multiplied with random number α. The *deadline function* is defined as β (M1+M2) + γ * deadline time where β , γ are factors decided based on the best optimization and β+ γ = 1. The schedule sequence is arranged in ascending order as per *deadline function* value. The ordered sequence is split into 12 sets of sequences and each set shall have 4 jobs/heats. In each set start time, waiting time and deadline variation is computed. If the dead line variation is minimum, that scheduling sequence is declared as best optimized sequence.

IV. METHODOLOGY

In this paper the authorstook 48 jobs with Processing Times on M_1 and M_2 i.e LD Converter Blowing time (t_1) and Argon Rinsing time (t_2) as shown in table 4.1.The deadline time for each job is calculated using function $\alpha*(t_1+t_2)$ where t1,2 are processing times and α is random number varies between 2 and 4. The scheduling at LD converter and ARS stations is done using EDF methodology on the data presented in Table 4.1 and it is compared with FCFS and SJF. Various Performance metrics like Average Turnaround Time (ATT), Average Waiting Time (AWT), Total Elapsed Time (TET) and dead line deviation is computed and compared. Java simulation programme is developed to compute all scheduling methods. Out of 48 jobs, it is considered that each 4 jobs/heats will run on one stream of Virtual machines M1 and M2 accordingly the computations are done. So that starting times after four jobs / heats will become zero for the first job/heat in that stream.

Waiting Time of a job request is the time elapsed between the arrival time of job request and whenthe job request starts its work on Machine of type-1, plus the time elapsed between the timeit completes its work on Machine of type-1 and starts its work on Machine of type-2.The Total Elapsed Time of the entire schedule is the time when all job requests completed theirwork on both machines of type-1 and type-2 respectively. Total Elapsed time of thisschedule is the c_k , where k is the last request in the schedule given by the scheduling algorithm.The performance metrics can be computed by the following computations for a given schedulingsequence.Average Waiting Time (AWT), Average Turn-around Time(ATT), Total Elapsed Time (TET) of alljob requests can be computed as follows.

$$AWT = \sum_{i=1}^{i=n} \left((c_i - t_{i2}) - (s_i + t_{i1}) \right) / \text{n}$$

$$ATT = \left(\sum_{i=1}^{i=n} c_i \right) / n$$

Where n : Number of jobs.

i : Job Request Number

t_{i1} : The time required on Machine of type-1 (M1) for job request ii.

t_{i2} : The time required on Machine of type-2 (M2) for job request ii.

c_i : Completion time of job request i Machine of type-2.

TET $= c_k$, where k is the last job request in schedule.

The authors have considered 48 Jobs on 2 types of Machines by considering 12 instances are available for each machine type. The dead line time is calculated using simulation programme for each heat or job id as (M1+M2) * Alpha. This is shown in Table I and algorithm used for EDF scheduling is shown in Algorithm 3.1.Where Alpha is the random number between 2 and 4. The dead line indicates the job to be completed within that time otherwise dead line deviation which is shown in Table 4.2.

TABLE: I. The Job Id, M1 , M2 , Alpha and Dead Line values

Job ID	M1	M2	Alpha (2 to 4)	Dead Line (M1+M2) * Alpha
0	15	32	2	94
1	19	25	4	176
2	17	25	4	168
3	16	20	3	108
4	17	20	2	74
5	18	27	2	90
6	18	12	3	90
7	20	32	3	156
8	19	17	4	144
9	18	42	3	180
10	17	14	2	62
11	19	10	2	58
12	15	17	3	96
13	18	22	4	160
14	17	18	2	70
15	16	28	2	88
16	16	25	3	123
17	15	12	2	54
18	17	22	4	156
19	18	24	3	126
20	15	14	3	87
21	18	32	4	200
22	17	95	2	224
23	17	19	2	72
24	23	19	3	126
25	18	25	3	129
26	10	19	3	87
27	17	23	4	160
28	17	14	3	93
29	18	22	2	80
30	22	14	3	108
31	17	35	2	104
32	17	22	2	78
33	27	15	2	84
34	18	8	3	78
35	17	10	2	54
36	18	9	4	108
37	18	23	4	164
38	17	11	3	84
39	20	12	3	96
40	21	25	4	184
41	17	14	3	93
42	18	32	3	150

43	18	10	2	56
44	18	13	2	62
45	17	20	4	148
46	17	20	2	74
47	10	25	3	105

ALGORITHM I

The algorithm for generating scheduling sequences and calculation of the above results is shown below.

Algorithm : Pseudo-code for EDF Scheduling Algorithm

Input : n number of job requests with processing time's t_{i1} and t_{i2} on Two types of M1 and M2 Machine
p number of instances are available for each Machine
$d1_i$ is deadline of i^{th} job request = Alpha * ($t_{i1} + t_{i2}$)
$2 \leq$ Alpha ≤ 4
(Beta + Gama) = 1

Output : Optimal Scheduling sub sequences Seq_1, Seq_2, $Seq_3, \ldots Seq_p$

```
begin
  i=0;
solution vector = empty;
   for each job request r_i with minimum (Beta*dl_i + Gama*((t_i1 + t_i2)) among all unprocessed
 jobs do
          add the job request r_i to the solution vector at index i;
          i=i+1;
   end for;
   for i=0 to n-1 do
      j = i % p;
      append solution vector[i] to the scheduling sub sequence Seq_j;
   end for;
   for i=1 to p do
      calculate performance metrics for each scheduling sub sequence Seq_i;
   end for;
 calculate aggregate performance metrics for the entire scheduling sequence;
end;
```

The AlgorithmI shows the methodology in computing performance metrics using EDF, FCFS and SJF scheduling and the results are shown in Table I.

V. ANALYSIS AND COMPARISION OF RESULTS

Using the Java simulation programming the FCFS, SJF and EDF scheduling results computed and the results are tabulated below.

A. FCFS Scheduling Results:

Forty eight jobs/Heats of different grades are scheduled on First Cum First Basis and there are scheduled on LD Converters First (M1) and Argon Rinsing Units next (M2). The start time of Job/ Heat on M1, Finish time of job on M2, Waiting Time (WT) and dead line and dead line violation is computed using computer programming as per the formulas mentioned above. In the set of heats below every four heats are scheduled on one set of M1 and M2 . Total 12 LD converters and 12 Argon Rinsing units are used and parelley processing the heats. The elapsed time for each set of machines processing calculated. The results are shown in Table II. The average elapsed time is 112 minutes and it is shown in Table III.

TABLE II. The FCFS scheduling computation results

Job ID	M1	M2	Start Time Of job on M1	Finish Time of Job on M2	WT	Dead Line	Dead Line Violation
0	15	32	0	47	0	94	0
1	19	25	15	72	28	176	0
2	17	25	34	97	55	168	0
3	16	20	51	117	81	108	9
4	17	20	0	37	0	74	0

5	18	27	17	64	19	90	0
6	18	12	35	76	46	90	0
7	20	32	53	108	56	156	0
8	19	17	0	36	0	144	0
9	18	42	19	79	19	180	0
10	17	14	37	93	62	62	31
11	19	10	54	103	74	58	45
12	15	17	0	32	0	96	0
13	18	22	15	55	15	160	0
14	17	18	33	73	38	70	3
15	16	28	50	101	57	88	13
16	16	25	0	41	0	123	0
17	15	12	16	53	26	54	0
18	17	22	31	75	36	156	0
19	18	24	48	99	57	126	0
20	15	14	0	29	0	87	0
21	18	32	15	65	15	200	0
22	17	95	33	160	48	224	0
23	17	19	50	179	143	72	107
24	23	19	0	42	0	126	0
25	18	25	23	67	24	129	0
26	10	19	41	86	57	87	0
27	17	23	51	109	69	160	0
28	17	14	0	31	0	93	0
29	18	22	17	57	17	80	0
30	22	14	35	71	35	108	0
31	17	35	57	109	57	104	5
32	17	22	0	39	0	78	0
33	27	15	17	59	17	84	0
34	18	8	44	70	44	78	0
35	17	10	62	89	62	54	35
36	18	9	0	27	0	108	0
37	18	23	18	59	18	164	0
38	17	11	36	70	42	84	0
39	20	12	53	85	53	96	0
40	21	25	0	46	0	184	0
41	17	14	21	60	29	93	0
42	18	32	38	92	42	150	0
43	18	10	56	102	74	56	46
44	18	13	0	31	0	62	0
45	17	20	18	55	18	148	0
46	17	20	35	75	38	74	1
47	10	25	52	100	65	105	0
							295

TABLE III. The sub scheduling sequences and elapsed time of schedule

Sub Scheduling Sequences	Elapsed Time of Schedule
FCFS Seq0 is : { 0, 1, 2, 3 }	117
FCFS Seq1 is : { 4, 5, 6, 7 }	108
FCFS Seq2 is : { 8, 9, 10, 11 }	103
FCFS Seq3 is : { 12, 13, 14, 15 }	101
FCFS Seq4 is : { 16, 17, 18, 19 }	179
FCFS Seq5 is : { 20, 21, 22, 23 }	109
FCFS Seq6 is : { 24, 25, 26, 27 }	109
FCFS Seq8 is : { 32, 33, 34, 35}	89
FCFS Seq9 is : { 36, 37, 38, 39 }	85
FCFS Seq10 is : { 40, 41, 42, 43 }	102
FCFS Seq11 is : { 44, 45, 46, 47 }	100
Average	112

B. SJF Scheduling Results:

In this jobs/ heats are arranged in the order of Shortest Job i.e. total time of processing on LD Converters (M1) and Argon Rinsing Units (M2) together. After arranging the heats in Shortest Job First basis, each set of four heats are processed on one set of M1 and M2. The Start Time, Finish Time, Waiting Time, dead line and dead line violation is computed for each heat and shown in Table IV. The total averaged elapsed time is 109.97 minutes and it is shown in Table V.

TABLE IV. The results of SJF Scheduling

Job ID	M1	M2	Start Time Of job on M1	Finish Time of Job on M2	WT	Dead Line	Dead Line Violation
0	15	32	52	106	59	94	12
1	19	25	52	99	55	176	0
2	17	25	34	79	37	168	0
3	16	20	10	49	13	108	0
4	17	20	35	72	35	74	0
5	18	27	47	97	52	90	7
6	18	12	0	30	0	90	0
7	20	32	53	110	58	156	0
8	19	17	15	51	15	144	0
9	18	42	57	118	58	180	0
10	17	14	0	31	0	62	0
11	19	10	0	29	0	58	0
12	15	17	15	47	15	96	0
13	18	22	28	75	35	160	0
14	17	18	17	52	17	70	0
15	16	28	55	105	61	88	17
16	16	25	34	76	35	123	0
17	15	12	0	27	0	54	0
18	17	22	38	77	38	156	0
19	18	24	35	78	36	126	0
20	15	14	0	29	0	87	0
21	18	32	44	104	54	200	0

22	17	95	51	174	62	224	0
23	17	19	18	54	18	72	0
24	23	19	34	76	34	126	0
25	18	25	52	97	54	129	0
26	10	19	0	29	0	87	0
27	17	23	30	70	30	160	0
28	17	14	0	31	0	93	0
29	18	22	34	74	34	80	0
30	22	14	19	55	19	108	0
31	17	35	68	120	68	104	16
32	17	22	35	74	35	78	0
33	27	15	41	83	41	84	0
34	18	8	0	26	0	78	0
35	17	10	0	27	0	54	0
36	18	9	0	27	0	108	0
37	18	23	26	72	31	164	0
38	17	11	0	28	0	84	0
39	20	12	18	50	18	96	0
40	21	25	46	100	54	184	0
41	17	14	18	49	18	93	0
42	18	32	50	108	58	150	0
43	18	10	0	28	0	56	0
44	18	13	17	48	17	62	0
45	17	20	17	54	17	148	0
46	17	20	17	54	17	74	0
47	10	25	18	53	18	105	0
							52

TABLE V. The sub scheduling sequence and elapsed time of schedule

Sub Scheduling Sequences	**Elapsed Time of Schedule**
SJF Seq0 is : { 34, 41, 4, 25 }	97
SJF Seq1 is : { 35, 44, 32, 1 }	99
SJF Seq2 is : { 36, 39, 18, 15}	105
SJF Seq3 is : { 17, 12, 27, 5}	97
SJF Seq4 is : { 43, 47, 13, 40 }	100
SJF Seq5 is : { 38, 14, 29, 0}	106
SJF Seq6 is : { 20, 8, 16, 42}	108
SJF Seq7 is : { 26, 3, 37, 21 }	104
SJF Seq8 is : { 11, 30, 33, 31 }	120
SJF Seq9 is : { 6, 23, 19, 7 }	110
SJF Seq10 is : { 28, 45, 24, 9 }	118
SJF Seq11 is : { 10, 46, 2, 22 }	174
Average	109.72

C. EDF Scheduling Results:

The model randomly determines a factor for each job/heat and finds out a *deadline time* for each job/heat. After deadlines are arrived for each heat / job the jobs are ordered based on the *deadline function* in ascending order is sequenced. The scheduling model considers for each 4 jobs/heats it sequences on one stream of LD converter (M1) and Argon rinsing station (M2). The start time of Job on M1,Finish Time of Job on M2, Wait Time, Dead Line and Dead Line Violation is computed for each Job ID / Heat Id and tabulated in Table VI. The Dead Line Time (DLT) is computed with (M1 + M2) * Alpha and Alpha is a random value between 2 to 4. The Dead Line Function is computed based on the formula β * DLT + γ * (M1 + M2). Where Beta and Gamma are chosen randomly such that Beta + Gamma = 1.In this research β is taken as 0.4 and γ is taken as 0.6. Based on the Dead Line Function the sequence is ordered in ascending form.The dead line variation is difference between dead line and finish time of job on M2. If it is negative the dead line violation is zero otherwise it is same positive value. This indicates that the job/heat is completed within the dead line time then there is dead line violation. The average elapsed time is computed for the overall heats produced on all the set of machines and the value is 106 minutes, shown in Table VII.

TABLE VI. The Shortest Job Scheduling Results

Job ID	M1	M2	Start Time Of job on M1	Finish Time of Job on M2	WT	Dead Line((M1+M2)* α	Alpha (2 to 4)	Dead Line Violation
0	15	32	35	89	42	94	2	0
1	19	25	67	111	67	176	4	0
2	17	25	51	101	59	168	4	0
3	16	20	37	73	37	108	3	0
4	17	20	0	37	0	74	2	0
5	18	27	17	62	17	90	2	0
6	18	12	19	49	19	90	3	0
7	20	32	52	119	67	156	3	0
8	19	17	33	82	46	144	4	0
9	18	42	50	121	61	180	3	0
10	17	14	0	31	0	62	2	0
11	19	10	0	29	0	58	2	0
12	15	17	17	54	22	96	3	0
13	18	22	50	111	71	160	4	0
14	17	18	0	35	0	70	2	0
15	16	28	17	65	21	88	2	0
16	16	25	35	76	35	123	3	0
17	15	12	0	27	0	54	2	0
18	17	22	43	82	43	156	4	0
19	18	24	37	79	37	126	3	0
20	15	14	17	46	17	87	3	0
21	18	32	52	114	64	200	4	0
22	17	95	52	177	65	224	2	0
23	17	19	0	36	0	72	2	0
24	23	19	44	86	44	126	3	0
25	18	25	32	79	36	129	3	0
26	10	19	15	46	17	87	3	0
27	17	23	53	96	56	160	4	0
28	17	14	18	49	18	93	3	0
29	18	22	17	57	17	80	2	0

30	22	14	35	71	35	108	3	0
31	17	35	35	87	35	104	2	0
32	17	22	18	57	18	78	2	0
33	27	15	17	59	17	84	2	0
34	18	8	0	26	0	78	3	0
35	17	10	0	27	0	54	2	0
36	18	9	25	55	28	108	4	0
37	18	23	57	98	57	164	4	0
38	17	11	0	28	0	84	3	0
39	20	12	17	49	17	96	3	0
40	21	25	55	104	58	184	4	0
41	17	14	18	49	18	93	3	0
42	18	32	42	103	53	150	3	0
43	18	10	0	28	0	56	2	0
44	18	13	0	31	0	62	2	0
45	17	20	35	82	45	148	4	0
46	17	20	0	37	0	74	2	0
47	10	25	32	71	36	105	3	0
								0

TABLE VII. The sub scheduling Sequence and Elapsed Time of Schedule

Sub Scheduling Sequences	Elapsed Time of Schedule
EDF Seq0 is : { 17, 26, 36, 18 }	82
EDF Seq1 is : { 35, 20, 47, 42 }	103
EDF Seq2 is : { 43, 32, 0, 13 }	111
EDF Seq3 is : { 11, 6, 3, 27 }	96
EDF Seq4 is : { 10, 29, 30, 37 }	98
EDF Seq5 is : { 44, 28, 31, 7 }	119
EDF Seq6 is : { 34, 41, 16, 2 }	101
EDF Seq7 is : { 14, 33, 24, 1 }	111
EDF Seq8 is : { 23, 39, 19, 40 }	104
EDF Seq9 is : { 4, 12, 25, 9 }	121
EDF Seq10 is : { 46, 15, 8, 21 }	114
EDF Seq11 is : { 38, 5, 45, 22 }	117
Average	106

D. Comparison of Results

The Average Elapsed Time, Total Dead Line Violation ofthe EDF scheduling model when compared with FCFS and SJF is shown in Table VIII. The graphical comparison of Scheduling Model and Average Elapsed Time is shown in Figure 2. The graphical Comparison of Scheduling moel and Total Dead line Violation is shown in Figure 3. These values indicates that EDF (106) scheduling model is better than the FCFS (109) and SJF (112) . The total deadline violation values indicates that the EDF (0.0) scheduling is giving much better results when compared with SJF (52.0) and FCFS (295.0).

TABLE VIII. The scheduling model viz. Average Elapsed Time, Total Dead Line Violation

Scheduling Model	Average Elapsed Time	Total Deadline Violation
FCFS	109.00	295.00
SJF	112.00	52.00
EDF	106.00	0.00

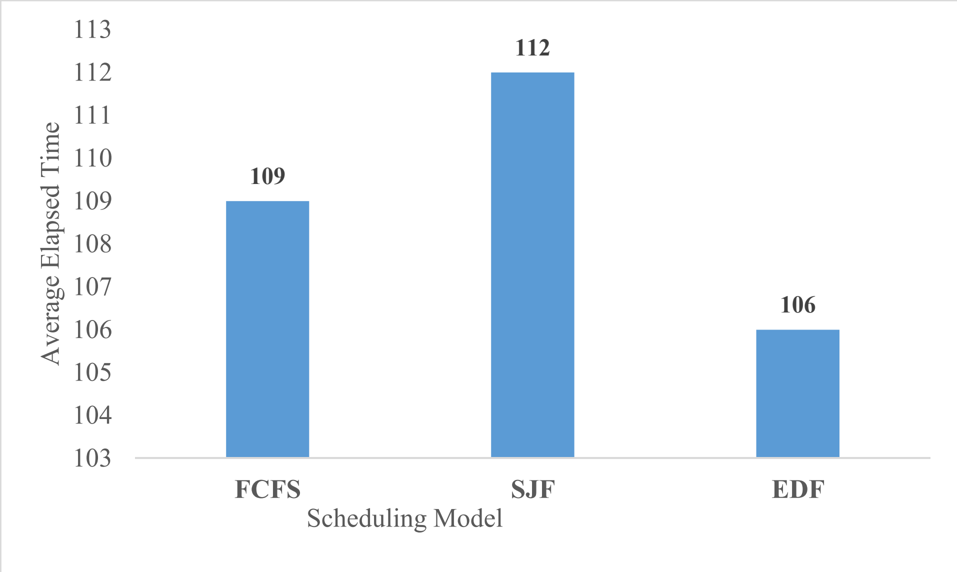

Fig.2 Averaged Elapsed Time variation with Scheduling Model

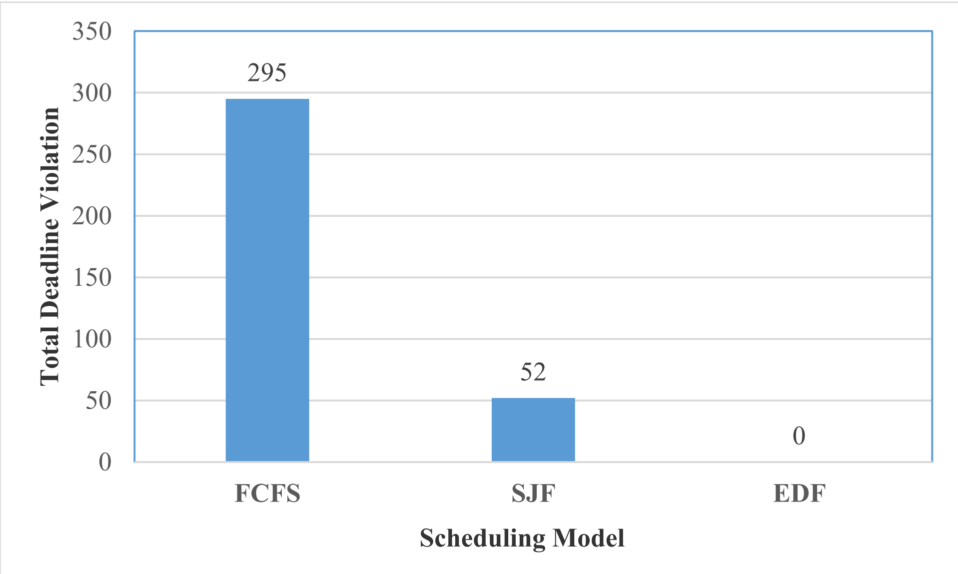

Fig.3 Variation of Total Deadline variation with scheduling model

VI. CONCLUSION

In this research EDF model is used for scheduling the heats at LD converter and ARS Stations. The scheduling results are compared with other conventional models viz FCFS and SJF. The result shows that EDF Model performance in terms of total deadline violation is much better than other FCFS and SJF, this implies that the deviation from deadline time is much less and better than others. The average elapsed time for a job in the case of EDF is better than FCFS and SJF.

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