Energy Management in Welding Intensive Industrial Cluster: Energy Saving opportunity

Shankara Naik, Mallur S B, Virupaxi Bagodi, Laxmana Naik L, P P Revankar

Abstract*: *The reported research explains energy saving opportunity in welding process dominated industry carried out for different small and medium scale enterprises that produce components for agricultural applications. The study concentrates the energy audit on the agricultural implements and tractor trailer industries as the agriculture is the main occupation of India. A total number of 15 small and medium scale industries are considered for the energy audit. The investigations revealed welding operation as a major energy consumer in agriculture implement industries contributing to about 84% of the total energy consumption. The welding machine efficiency varies from 35% to 50% in the considered industrial clusters. Based on the results it is suggested that the energy saving can be increased by 40% - 45% by adoption of inverter arc welding technology.

Keywords: About four key words or phrases in alphabetical order, separated by commas.

I. INTRODUCTION

Small and medium enterprises (SMEs) are recognized as the backbone or engine to economic development of any country as they generate employment and wealth [1]. Growth of SMEs is a means to attain equitable development of nation. Even with their vital contributions to the nation, SMEs face the closure threat on account of the higher energy consumption that in turn leads to environment degradation. It is in this context that it was identified to be important to study the present energy consumption pattern in the SMEs to suggest or for the adaptation of new/modern technology for efficient energy techniques and for the cleaner production. Energy is essential to achieve economic, social and environmental objectives of the sustainable human development [2]. The relationship between use of energy and economic growth has been a subject of inquiry as it is considered to be one of the important driving forces of economic growth in developed and developing countries [1]. For any country, the supply and appropriate use of effective energy is a primary condition for economic development [3]. One of the main pillars of modern industry is uninterrupted supply of energy at a reasonable price [4].

The various forms of energy used in Indian Industry include electrical energy, thermal energy and natural gas energy. The electricity is main source of energy for the small scale industries (SSI) that are found consume around 76% of total energy consumption. Subramanian [5] conducted survey of SSI units in Karnataka and their analysis assert that the energy saving potential in SSI can be increased up to an extent of 32%. Schulze et al. [6] reviewed the previous findings on energy management in industries and reported that energy management leads to large energy savings which remains untapped. Energy management is the combination of energy efficiency activities, techniques and management of related processes [7]. Energy management helps achieve competitiveness in industries [8]. Anisimova [9] analysed the energy management in the Russian enterprises and noted that there is a lack of information on positive effects of the application of energy management system. Further, researchers assert that the management is merely interested in obtaining the certification

From the aforementioned literature, it is clear that the energy management is more important in economic and technical issues which are varied out effectively by energy audits. Authors found that there are very limited studies on energy audit of jeans garments, agriculture implements and tractor trailers, food products, and coir and coir products clusters. The present study concentrates on the energy audit of agricultural industries which mainly uses the electrical energy as the main source of energy for different processes. For this purpose a total 15 SMEs are selected for the investigation of energy losses occurring at the various sections of the industries and the consumption of energy by the different sections in the industry is reported. Based on the results a possible alternative method to minimize the energy loss is suggested. Further, contribution of alternative technique on the emission rate is also highlighted

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II. METHODOLOGY

The present study involves the systematic auditing of SMEs involved in manufacture of agriculture equipment in the area covering Hubli-Dharwad industrial cluster in Karnataka state of India. The present work explains the selection of industries, pre energy audit phase and detailed energy audit phase. In the pre audit phase the details of machine, equipment and appliances used in the industry is collected and finally identified the measuring instruments required for conducting the energy audit. The detail audit involves the estimation of energy consumption and losses for each and every machine/equipment driven by different ratings of the motors in the industries.

In the present work, the performance study of welding machine is carried out to investigate the working condition, energy consumption and efficiency. The performance characteristics of the welding machine obtained from the industries is compared with the latest welding technology.

A. Selection of Industries

MSMEs prevail, mostly, in the form of clusters. Cluster is a sectorial and spatial concentration of firms [10]. MSMEs are found in clusters in India due to access to semi-skilled labour pool, availability of raw materials and nearness to market. There are more than 2000 artisan based rural clusters and about 140 in and around urban areas. United nation industrial development organization (UNIDO) has identified 19 clusters in Karnataka state, India [11]. The report further states that jeans garment cluster has high export potential while leather products cluster and agriculture implements and tractor trailers (AITT) have to be upgraded with latest technology. The AITT cluster at Hubli, Karnataka, India, with about 130 industries has been investigated to a limited extent and reported in research publications. In the present investigation around 15 AITT industries are selected for conducting the energy audit study.

B. Pre Energy Audit Phase

The pre energy audit involves preliminary communication with the different levels of industry beginning from top management to the shop floor workforce to take confidence of each section of the industry. Audit was conducted through identified set of measuring instrument to perform a scientifically proven investigation of the energy consumption pattern at the industries. The preliminary energy audit phase recorded the technical specifications and information related to machines and equipment used in the industry. The available equipment and machinery operations in AITT Cluster at Hubli are given Table I along with their respective power ratings. The prominent equipment's in AITT industry are arc welding machine, lathe, drilling machine, cut off saw, power hack saw, painting set up, bench grinder and shearing machine. The auxiliary power consumption for illumination and fans were also considered in the pre audit assessment of the AITT industry cluster. The preliminary audit is carried out in 130 AITT industrial clusters.

Table- I: Capacity of Equipment/ Machines

AITT Industry	Sl. No.	1	2	3	4	5	6	7	8	9	10	11	12
	Equipment / Machinery	*Arc Welding M/C*	*Angle/ Hand Grinder*	*Bench Grinder*	*Cutting Machine*	*Cut off Saw*	*Drilling*	*Lathe*	*Power Hacksaw*	*Painting Set Up*	*Shearing /Power Press*	*Lighting and Fan Load (hp)*	*Total load (hp)*
A	Capacity-No.	18hp-3	3hp-2	1hp-1	15hp-1	3hp-1	2hp-1, 3hp-1	3hp-1, 5hp-1	2hp-1	2hp-1	15hp-1	0.66	111.66
B	Capacity-No.	18hp-3	3hp-2	1hp-1	---	3hp -1	2 hp-1, 3hp1	3hp-1, 5hp-1	2hp-1	2hp-1	---	0.48	83.48
C	Capacity-No.	18hp-2	3 hp-2	1hp-1	---	3hp-1	1hp-1	3hp-1	1hp-1	2hp-1	---	0.76	53.76
D	Capacity-No.	18hp-2	3hp-2	1hp-1	---	3hp-1	1hp-1, 3hp-1	3hp-1	2hp	2hp-1	---	0.5	57.5
E	Capacity-No	18hp-2	3hp-2	1hp-1	10hp-1	3hp-1	2hp-1, 5hp-1	3hp-1	1hp-1	2hp-1	10hp-1	0.56	79.56
F	Capacity-No.	18hp-3	3hp-2	1hp-2	15hp-1	3hp-1	2hp-1 ,3hp-1	3hp-1	2hp-1	3hp-1	15hp-1	2	109
G	Capacity-No.	18hp-3	3hp-2	1hp-2	---	3hp-1	1hp-1	3hp-1	1hp-1	2hp-1	---	1.05	75.05
H	Capacity-No.	18hp-2	3hp-2	1hp-1	---	3hp-1	1hp-1	3hp-1	1hp-1	1hp-1	---	0.75	52.75
I	Capacity-No.	18hp-3	3hp-2	1hp-1	---	3hp-1	1hp-1	3hp-1	1hp-1	1hp-1	---	0.54	52.54
J	Capacity-No.	18hp-3	3hp-2	1hp-1	---	3hp-1	1hp-1	3hp-1	1hp-1	1hp-1	---	0.76	52.76
K	Capacity-No.	18hp-3	3hp-2	1hp-1	---	3hp-1	1hp-1	3hp-1	1hp-1	1hp-1	---	0.75	68.75
L	Capacity-No.	18hp-3	3hp-2	1hp-1	15hp-1	3hp-1	2hp-1	3hp-1, 5 hp-1	1hp-1	1hp-1	15hp-1	1.6	102.6
M	Capacity-No.	18hp-2	3hp-2	1hp-1	10hp-1	3hp-1	2hp-1, 3hp-1	3hp-1	1hp-1	2hp-1	10hp-1	0.32	75.32
N	Capacity-No.	18hp-2	3hp-2	1hp-1	10hp-1	3hp-1	2hp-1, 3hp-1	3hp-1	1hp-1	2hp-1	10hp-1	0.32	61.32
O	Capacity-No.	18hp-2	3hp-2	1hp-1	---	3hp-1	2hp-1, 3hp-1	3hp-1, 5 hp-1	1hp-1	2hp-1	---	1.04	58.04

(1) is . . .”

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C. Detailed Energy Audit Phase

The detailed energy audit is performed for a three month duration spanning between October to December, 2017, and gathered data of energy consumption of each equipment and machinery. The instruments used for the detailed energy audit includes tachometer, tong tester, power factor meter, energy-meter and digital measuring tape. A detailed energy audit is carried out for fifteen agricultural implements and tractor trailer industries.

Fig. 1 shows the summary of energy consumption pattern in different agricultural implements and tractor trailers at Hubli, during above said study period. From the audit it is found that the welding machine is consuming 83.61% of the total energy consumed by the industry out of which 53.23% is noted during the working condition period and is shown in Fig. 1. The average energy consumed by the agriculture implements and tractor trailer industries is 1558.4 kWh / month. It is also noticed that the major energy consumption is by welding machine used at different sections of the industry. Hence, the present study is focussed on the energy consumption and performance of transformer arc welding machine.

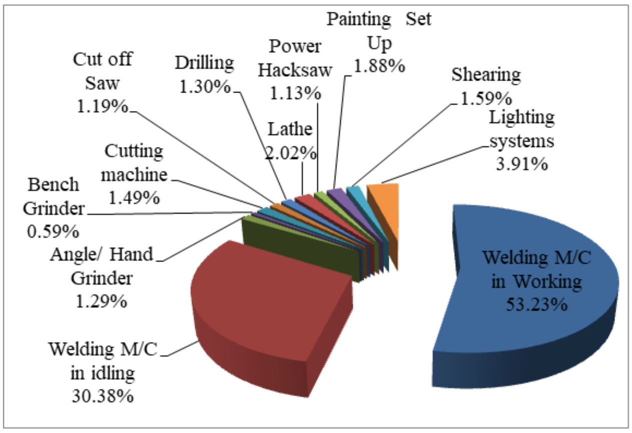

Fig. 1. Energy Consumption Pattern.

D. Performance Test of Rectifier Transformer Arc Welding Machine

The performance test of rectifier transformer arc welding machine is carried out at Hubli - Dharwad (Situated in Karnataka state, India) cluster of agricultural implements and tractor trailers. It is observed that almost all the industries are using obsolete technology, i.e transformer arc welding. It is noticed that the welding machine consumes 2.09 to 3.66 kWh of energy during idling condition and 10 to 14.5 kWh during working conditions. Figure 2 shows the variation of energy consumption during idling and working conditions that is recorded in four months period. It is observed that the industry D and K consume more energy than the rated capacity of the welding machine due to improper maintenance, use of skinned welding cable and because of older machine.

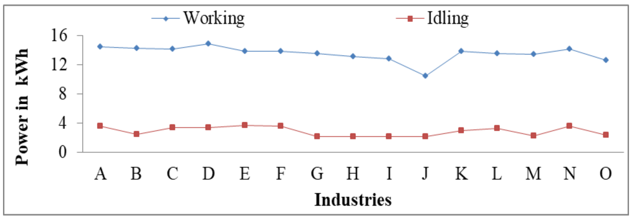

Fig. 2. Welding Machine Power consumption

The J industry shows the minimum energy consumption among all the industries studied. During the idling condition, the power factor of welding machine is below 0.3 that enhances the power consumption of the enterprise. The output voltage in the open circuit varies from 50 to 70V for studied industries. These voltages are termed as safe voltage, which leads to overheating of welding cables, reduced life of welding cable and risk of shocks.

It is noticed that the rated capacity and average efficiency of considered industries are 16 kVA and 45.14% respectively. The variation of efficiency of the welding machine for different industries is shown in Fig. 3. It is observed that the efficiency of the welding machine varies from industry to industry because of the different working condition and maintenance. From the plot it is clear that the industries J and H give the maximum and minimum efficiency respectively. This is due to the fact that the industry J consumes minimum energy as shown in Fig. 2.

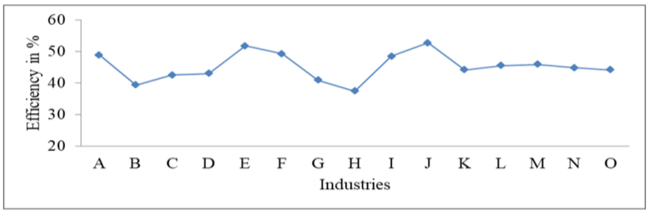

Fig. 3. Welding Machine Efficiency

The average idling and working time of the welding machine is 163.6 hours/month and 61.57 hours/month, respectively. Figure 4 shows the energy consumption of arc welding machines in idling and working conditions in addition to average consumption. It is noticed that the industries G and O consumes maximum and minimum energy respectively.

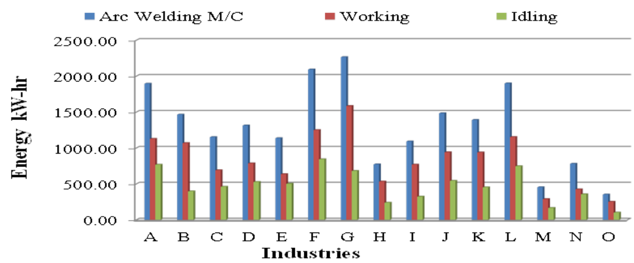

Fig. 4. Welding Machine Energy Consumption

The working and idling hours of the welding machine plays a vital role in energy consumption rate as well as on the efficiency of the machine. In this context the study is extended to determine the working and idling hours of the individual industries. Figure 5 shows the working and idling hours for the month of November 2017.

It is noticed that the industry G gives the maximum and minimum hours for both the conditions. This is because the energy consumption rate is found to be more for the industry G as shown in Fig. 4. Similarly, the industry O also shows the same results. This indicates that the rate of energy consumption is dependent on the hours of working and idling period. Though the energy consumption is more during the working period, the loss of energy during idling time is proved to be critical. The efficiency of the transformer arc welding machine depends

on machine life and its maintenance. The proper maintenance of welding machine by power factor correction,

cooling and avoiding skin reduces the energy consumption by 5 to 10% and enhances the efficiency. Based on the results, author proposes the alternate method to reduce

energy consumption and to enhance the safe working condition of the welding machine. The welding machines are good in power factor and less weight with better output voltage of 4 to 12V during the idling condition. This voltage is termed to be safe voltage which also reduces the overheating of the cable and free from shock. For this purpose the existing transformer rectifier arc welding can be replaced by inverter power source wielding machine. The amount of energy saving is calculated by the Eq. (1).

$$\text{Monthly energy saving} = (E_t - E_i) + \frac{\text{kW}}{\text{month}}(\eta_i - \eta_t) \quad (1)$$

Where, E_i and E_t are energy consumption per month in idling condition for inverter power base welding machine and rectifier transformer welding machine. The η_i and η_t are the efficiency of the inverter power base welding machine and rectifier transformer welding machine.

The Eq. (2) and (3) gives the power consumption calculated for transformer arc welding and inverter power base welding machine.

$$E_t = \text{Total power consumed by industry} \times 0.3038 = 473.44 \quad (2)$$

$$E_i = \textit{Average idling time} \times \textit{idling power comsuption in kW} = 163.6 \times 0.1 = 16.36\, kW \frac{hr}{mont\ h} \quad (3)$$

The power consumed by the transformer rectifier arc welding (TAW) machine during working condition is calculated in kWh.

Equation (4) is used to calculate the amount of energy used by the welding machine during working condition.

$$\frac{kWh}{month} = \textit{total power consumed by the industry} \times 0.5323 = 1558.4 \times 0.5323 = 829.54\, kW \frac{h}{month} \quad (4)$$

The energy consumption by welding machine during idling condition in terms of units per month is calculated by Eq. (5). Similarly the energy saving cost by monthly basis in terms of Rupees is given by Eq. (6) and calculations are shown in Eq. (7).

$$\textit{Monthly energy saving in Rs.} = (473.44 - 16.36) + 829.54\,(0.90 - 0.4514) = 457.08 + 372.13 = 829.12 \frac{Units}{month} \quad (5)$$

$$\textit{Monthly saving in Rupees} = \frac{\textit{cost in Rs.}}{\textit{units}} \times \frac{\textit{units}}{\textit{month}} \quad (6)$$

$$\textit{Monthly saving in Rupees} = 6.35 \times 786.82 = Rs.5264.91/month \quad (7)$$

The cost and model of the welding machine varies with different manufactures out of which a general welding machine is selected for the study. The most commonly used TAWM in the agriculture implements and tractor trailer are rating from 14 kVA to 16 kVA (18HP), in this rating some of inverter power source welding machines technical specification and cost detailed given in Table II and Table III. This can be adopted for different models of the welding machines accordingly. The Eq. (8) shows the calculations of the payback period for 14kVA welding machines in terms of months. The technical data and cost details are considered for the one welding machine for the study.

Table- II: Technical Specification

<table>
<tr><th>Suitable Electrode Diameter</th><th>Input Power(KVA)</th><th>Current Range Amps</th><th>Duty Cycle</th><th>Weight (Kg)</th></tr>
<tr><td>1.6, 2.5, 3.2, 4, 5 and 6.3 mm</td><td>14</td><td>10-400</td><td>400A@60%, 310A@100%</td><td>24.5</td></tr>
<tr><td colspan="5">Input power Supply AC 415V±20 % ,3 Phase, 50 /60 Hz</td></tr>
<tr><td colspan="5">Open Circuit Voltage -75 volts, Power Factor= 0.95</td></tr>
<tr><td colspan="5">Efficiency at full load = 90% to 95% , Ambient Temperature = 40°C</td></tr>
</table>

Source: catalogues

Table- III: Price list

<table>
<tr><th>Name of the Make</th><th>Model No</th><th>Price in Rs.</th></tr>
<tr><td>Kemppi</td><td>S 400R</td><td>60000</td></tr>
<tr><td>Jasic</td><td>ARC 400IM Z312 ARC</td><td>43500</td></tr>
<tr><td>Cruxweld</td><td>CMM-ARC400i</td><td>345000</td></tr>
<tr><td colspan="2">Average price</td><td>46,000</td></tr>
</table>

Source: catalogues

Payback period for the 14kVA,

$$\frac{\textit{Initial investment in Rs.}}{\textit{Monthly saving in Rs.}} = \frac{34500}{5264.912} = 6.55\, \textit{months} \quad (8)$$

From the survey it is noticed that the average number of machines used in the industries are three. The calculations shown above are made assuming one machine in the industries. This reflects the payback period of 7 months approximately. This is actual case which may lead to a payback period of 20–24 months.

III. RESULTS AND DISCUSSION

The energy consumption of the various industries for a period of 12 months is collected from the audited electrical bills of the industry.

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The total energy consumption rate of individual industry is calculated; meanwhile the overall consumption rate by the 15 industries for individual month is noted. Table IV shows the variation of the energy consumption per month in kWh. The major total power consumption is observed by the industry G which is consuming 9.82% of the overall consumption by the all industry whereas industry O consumes minimum of 2.21% energy. The highly contrast of the energy consumption shown in Table 5 is due to the non-availability of work/job order.The energy consumed by the welding machine and other machines (bench grinder, power hacksaw painting set up, lathe machine) in the industry for a year is tabulated in Table V. From the table it is clear that the existing welding machine consumes 84% of the total industrial energy. This energy loss can be reduced about 45% by replacing the existing welding machine with the inverter welding technology.

Table- IV: Energy Consumption

Name of the industries	Months	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Total
	A	2221	1878	1666	1256	1648	1185	1319	1175	2657	2054	1571	2240	20870
	B	1256	1648	1185	1319	1175	2657	2054	1571	1259	1485	1725	1658	18992
	C	1259	1485	1725	1540	1394	1502	1071	1055	1227	1565	1112	2620	17555
	D	1493	1493	1493	3816	1254	1949	1486	1355	2573	1486	1355	1475	21228
	E	1102	2727	1419	2272	1250	3276	1924	1279	1835	1824	1760	1407	22075
	F	1565	1112	2620	1236	1347	1360	1115	1253	1799	1760	2040	2641	19848
	G	1360	1115	1253	1799	1760	2040	2040	3793	3793	2788	2788	2573	27102
	H	934	788	971	943	1055	926	897	723	1205	1205	966	931	11544
	I	1571	1259	1485	1725	1540	1394	1502	1071	1055	1227	1565	1242	16636
	J	982	1626	1102	2727	1419	2272	1250	3276	1924	1279	1835	1724	21416
	K	1626	1102	2727	1419	2272	1250	3276	1924	1279	1835	1824	1567	22101
	L	1236	1347	1360	1115	1253	1799	1760	2040	2040	3793	3793	2230	23766
	M	317	487	681	498	369	706	317	334	554	526	384	725	5898
	N	982	1626	1102	2727	1419	2272	1250	3276	1924	1279	1835	1060	20752
	O	587	372	378	415	481	364	630	542	482	764	534	549	6098
Total	275881	18491	20065	21167	24807	19636	24952	21891	24667	25606	24870	25087	24642	275881

Table- V: Energy Consumption and savings by replacing IWM

Months	Energy consumed by			Energy saved by replacing with IWM		Total energy consumed by industrial cluster
	In studied industries	TAWM	Other than TAWM	In studied industries	Industrial Cluster	
Jan-17	18491	15460.33	3030.67	8224.89	1069236.08	160255.33
Feb-17	20065	16776.35	3288.65	8925.02	1160252.12	173896.67
Mar-17	21167	17697.73	3469.27	9415.19	1223974.92	183447.33
Apr-17	24807	20741.13	4065.87	11034.28	1434456.74	214994.00
May-17	19636	16417.66	3218.34	8734.19	1135445.34	170178.67
Jun-17	24952	20862.37	4089.63	11098.78	1442841.32	216250.67
Jul-17	21891	18303.07	3587.93	9737.23	1265839.98	189722.00
Aug-17	24667	20624.08	4042.92	10972.01	1426361.28	213780.67
Sep-17	25606	21409.18	4196.82	11389.68	1480658.65	221918.67
Oct-17	24870	20793.81	4076.19	11062.31	1438099.69	215540.00
Nov-17	25087	20975.24	4111.76	11158.83	1450647.65	217420.67
Dec-17	24642	20603.18	4038.82	10960.89	1424915.67	213564.00
Total				122713.3	15952729.4	2390968.667

The overall energy consumption by the industries on monthly basis is recorded. Further, the energy consumption by the TAWM and other machines are also calculated. It is interesting to note that the emission of carbon di-oxide (CO_2), sulphur di-oxide (SO_2), carbon monoxide (CO), and nitrogen oxide (NO) is decreased with the use of inverter arc welding machine in the place of TAW machines.

The major constituents of emission are considered. In which the CO_2 is found to be major contributor for the emission. The rest of the constituents' viz., SO_2, NO, and CO shows similar trend of variation in the contribution on mass basis. The common trend indicates the significance of using inverter welding machine. The significant reduction of 88.67 % in CO_2 is observed which is shown in Figure 6. Figure 7 shows the variation of emission of gases on mass basis before and after the use of inverter welding machine. The demand of agricultural implements and tractor trailer is more during the period of September to December 2017. This is the reason for higher peak values during these months.

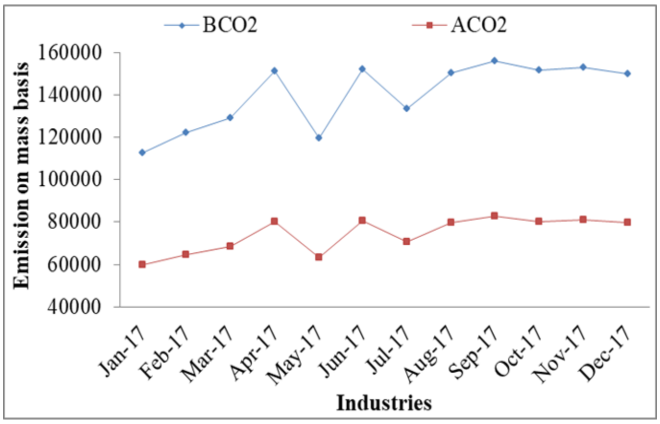

Fig. 6. CO_2 Emission Before and After Replacement of TAWM with Invertor Welding Machine

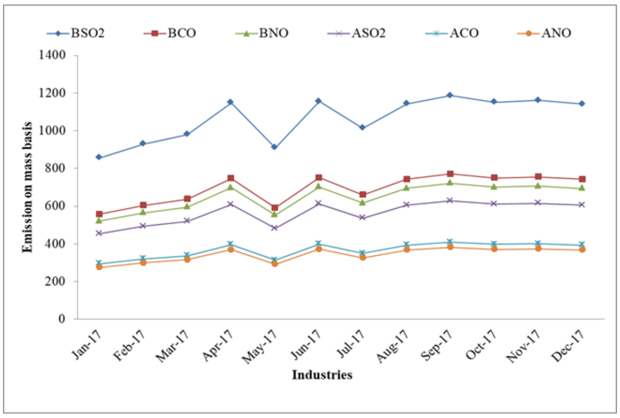

Fig. 7. Emissions Before and After Replacement of TAWM with Invertor Welding

IV. CONCLUSION

The reported energy audit identifies the energy saving opportunities in a cluster of fifteen AITT industries chosen for study with subsequent detailed energy audit made. The results of the detailed data analysis found that transformer arc welding machine consumed 84% of the total plant energy consumption. The replacement of old welding machine with inverter power source welding machine saves energy consumption about 40 to 45% by the industry. This also resulted in significant reduction of GHG and the payback period to 20 to 24 months. It was also observed that there is significant reduction in CO2 emission by 88.67% that reflects the environmental concern.

ACKNOWLEDGMENT

It is optional. The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank ... .” Instead, write “F. A. Author thanks ” *Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page*.

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