Alstom Locomotive AD43C Frequency Stabilizer, Reasons and Musts

An important modification on A/C system to save the environment

Mr. Shahram Vesali
M. Sc. Mechanical Engineering
Technical Consultant of World Part Supplier Co.
shvesali@gmail.com

Nowadays the air pollution and reducing the risks and dangers from this treatment side is the most important concern of the world and human community.

One of the most pollutant sources of the atmosphere are industrial and heavy-duty mechanical engines such as internal combustion ones used in railways as propulsion and power plants.

Alstom as one of the pioneers of railways industries designed and manufactured several freight locomotives. A model of those locomotives that Alstom built and sold to Iran is known as AD43C. A 3000 hp locomotive dedicated to heavy-duty applications in warm and dusty regions.

The air conditioning system of these locomotives works based on the frequency. The logic of this system can be described as:

Air Conditioner System receives the input power varied by the frequency of alternator. The rotational speed of electromotor transmits to compressor of air conditioner by means of belt. It means that the function of system can be optimized by controlling the input power of the system.

I. Introduction

The railway industry is a safe and trustable method to replace road freight services. Although each method that brings some advantages with itself, definitely will accompany some disadvantages as well.

In this argument, we concentrate on a type of railway freight locomotive model AD43C made by Alstom.

This locomotive is equipped by 16RK215 Ruston MAN, 3000hp engine. The application of this model that has been designed for Iran's railways is freight purposes.

The comfort and convenience appliances of each locomotive are one of the key factors for locomotive crew especially locomotive engineers. A locomotive air conditioner and/or air-cooling system is one of those welfare accessories especially if the locomotive is used in tropical regions.

Our client from Iran railways, asked us to study a case on their existing fleet of locomotives and introduce them a solution for the problem.

AD43C locomotives of Iran railway are equipped with an air conditioner system that operates based on the frequency generated by the locomotive alternator.

In other words, the air conditioner could have its best performance when engine runs in full load (full speed). Full load generates maximum round per minute (mechanical rotational speed). The maximum R.P.M of the RK215 engine is 850 rpm.[1]

The locomotive must run in the highest notch to get the most outcome of the system. The

[1] MAN B&W Diesel Engine Selection – Page 37 Table Ruston RK215 Rail Traction

explanation of this fact is that either locomotive or train is on the road or waiting for road permission, the engine has to be under full load to have the most outcome from the air conditioner.
This was the problem and we were hired to determine the best solution in the cheapest manner to fix it forever.

II. Discussion

Locomotives consume gasoline, which is one the main sources of pollutants. Regardless of the harm caused by this derivative of fossil fuels, we are dependent on it because it is yet the most reliable source of power for industrial internal combustion engines.

The world is trying to reduce the usage level of it by different means.

According to European regulations known as UIC as well as Northern American Railways regulation is known as AAR, all locomotive owners are obliged to control the output of the exhausts by reducing the emission level.

The Paris Agreement (UNFCC) obliges all nations and government to reduce the pollution as one of the methods of controlling climate change.[2]

Our client, who is a part of the Iran government, following this convention started this project.

A. CASE STUDY

The nature of discussed locomotives is freight application.

In most countries, especially in the Middle East, railways have not separated freight purpose and passenger purpose railways from each other. It means that the rail profile is universal for both applications of freight and passenger.

For whoever is familiar with railways it is known that in that condition, the first priority is for passenger trains rather than freight trains.

Knowing this fact, railway people admit that freight trains must stop in the stations often over 2 hours until, the train receives the permission of traffic.

Alstom AD43C locomotives are congenitally equipped with an air conditioner system, which is dependent on frequency generated by locomotive alternator.

Question1: What does the previous statement mean in the real operation?

Answer: It means that the air conditioner will provide the best output when it is getting the highest frequency. The highest frequency gets generated when the engine runs at full speed. The full speed of the engine causes a full load on the alternator. The full load of alternator creates the highest frequency. The highest frequency results in the best performance of air conditioner unit.

Question 2: Can the locomotive run with the engine full load circumstances while the train is stopped in a station?

Answer: Yes, it can. The locomotive engineer just needs to leave the regulator handle in the neutral position and accelerate the engine up to the highest speed.

Question 3: What are the problems?

Answer: The problems can be categorized as the following:

- Engine run at full speed when the train is stopped in the station, while it could run at neutral speed. The results of this fact can be listed as:
    - High rate of fuel consumption, while it is not necessary at all.
      The output of this act means:

[2] The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC), on climate change mitigation, adaption and finance signed by 2016.

- Considerable high rate of fuel consumption, whereas it could be much lower than the existing amount.

  The first affect of this reality is the economic influence for the owner of locomotive.

The specific fuel consumption of Engine 16RK215 is 199 gr/(kw.hr) as per ISO rating.[3]

Acknowledging this rate, assuming 2 hours working in idle position but in full load for a freight train, we will reach to almost 800 liters of gasoline.

The cost of this volume of fuel is a big loss that the modifying of air conditioner system can save. The total amount of saving per year is a considerable economical benefit.

- High rate of parts failure and maintenance costs is another side effect of the original air conditioning system.

Keeping parts and elements of the engine and alternator under the continuous stress of high load causes a shorter lifetime of parts. In fact, the rate of parts replacement and maintenance fee increases enormously because the welfare equipment of locomotive driver cab provides the best output when the locomotive runs at the highest speed.

Lack of precision in regular maintenance can cause big damages and very heavy and expensive overhaul costs.

On the other side, some parts or particles cannot be recycled so easily. A higher rate of parts exchange, can increase the garbage input to the environment which one of the obligations of the world based on UNFCCC to keep control of it and put the effort to reduce it.

  - Environmental pollutions that we can describe them as following:

- The allowed range of noise, known as criterion level of sound, abbreviated as Lc, according to Canadian Occupational Exposure the Limit, for a working environment, is 85 dBA.[4] Whereas the noise level of a heavy-duty engine in full load is above 102dBA.[5] Working at this level of noise for long time can lead to deafness in a period of time between ten to fifteen years. However, the risk of this noise affects the locomotive drivers and crew indirectly but other people around the locomotive directly.

Indirectly for the locomotive crew, because they sit in an insulated cabin that enormously reduces the level of sound before receiving it by ears.

Directly for other people, because they might be in direct exposure of sound waves without any shield or protection, such as workers who work in the open area or in the yard.

- ✓ When the engine runs in full load, the smoke output from exhaust is not comparable to the situation that the engine is running in idle condition.

Our studies show that the gasoline produced by our client's refinery factories contains a significant amount of Sulphur that is added to the fossil fuel as an additive just to lubricate the fuel and reduce the damages risks in internal combustion engines. We are not going to discuss more this matter. But we will consider it as one of the key and important factors in air pollution.

Sulphur in combination with oxygen and in presence of high temperature generated by engine and also the humidity, creates a dangerous compound that penetrates into plants.

Nowadays it is proven scientifically that those types of compounds in air pollutions are one the main reasons for genetic mutation and birth of defective creatures.

[3] NIGEL GEE AND ASSOCIATES LTD - Fast Ferry Powering and Propulsors

[4] Canadian Center for Occupational Health and Safety

[5] Measured practically on top of the engine hood of the locomotive in throttle eight – Full Load.

III. Solution

I believe that the frequency-based air conditioner is a self-inflicted objection done by Alstom to sell a corrective option of the problem for extra cost to the final client.

Since the air conditioner was frequency-based, it couldn't have different ranges of operation as instance, low and high cool.

We needed to make the system of the air conditioner independent from frequency. We focused on this logic and started designing a drive. We named it "Alstom Frequency Stabilizer System" (AFSS).

We designed a drive that independents the air conditioner from locomotive frequency. AFSS system runs with 74VDC input and converts it into 400 VAC 3-phase.

The system of AFSS is intelligent and controls every single element that we want it to measure and control. This drive controls input voltage. If the voltage tolerates beyond the setting, the system will consider it as a fault and will shut down temporarily until the failure and/or the reason of the failure gets fixed. The same procedure happens for input current.

The output is also monitored. Should any kind of failure sense, the system will stop operation and will keep a record of fault in its event logger for further analysis and investigation.

Despite the previous version of the air conditioner system that could run in cooling condition regardless of the ambient temperature and the season, our system controls the operation of the air conditioner according to the adjusted operational temperature range.

AFSS is programmable. In other words, the administrator of the system, who has access to the admin authority, can set the operative temperature of the unit. The admin can set the working range of the cabin as well as the minimum temperature that the air conditioner can work as a cooler. In opposite, we have the reverse condition for the system in heating condition. The admin can set the highest temperature that the system can work as a heater.

By verifying the set points of operations, the system will not work as cooler if the range of the ambient temperature is out of the set value and vice versa for the heating condition.

AFSS independents air conditioner system from frequency. It stabilizes air conditioner frequency. The logic of the primary system is kept untouched. The A/C system has a compressor that is linked to an electromotor by belt.

The electromotor's speed varies by input frequency in the original design. In our design, the input frequency is set at 60 Hz. We have designed 2 modes for the air conditioner system either in cooling or heating condition – High Cool or Heat, Low Cool or Heat.

An important note:

Our AFSS system keeps the wiring of the original design intact. It provides an opportunity for interchangeability of the system. Meaning that we provided an additional option for the client to convert the modified system to the original design by unplugging the AFSS harness and connecting the input power cords to the electromotor.

Suppose that for any reason, our drive, AFSS, fails but keeping locomotive or train in service is very important. Therefore, unplugging the AFSS from the system and reconnecting the input to the harness, will keep the air conditioner in running condition. Further troubleshooting can be done in the center afterward.

IV. Conclusion

By modifying the A/C system of Alstom AD43C locomotive to AFSS "Alstom Frequency Stabilizer System" the following advantages are obtained:

1. Saving enormous and considerable economical value of fuel per day and year.

2. Saving a huge amount of bill on extending the lifetime of parts and reducing the maintenance fee of the locomotive.
   We know that the major maintenance cost of locomotive belongs to engine

parts. If we change the durability of installed parts from 90 days to 120 days, in a very pessimistic and conservative point of view, the locomotive owner will save the cost of one period of maintenance, which is a reasonable amount and for the experts involved with railway and locomotive operation it is very important notice and familiar statement too.

3. Reducing the sound of the engine closer to the acceptable range, while the train is stopped in a steady place waiting for the permission.
   This matter not only helps human but also is a big help for other fauna. Because our ears can accept a certain range of dBA. Even so, the noise generated by the engine is very harmful to hearing. Another fauna has a wider range of sound survival but exposing a long time to noise, will infiltrate permanent effects on their hearing system.

4. Reduction of the exhausted smoke from the engine by running a locomotive in neutral speed is one of the goals of our designed system that complies totally with the Paris Agreement (UNFCCC).
   By reducing the volume of ejected smoke from the exhaust, we reduced the amount of released Sulphur to the atmosphere. It means reducing the risk of genetic mutation caused by this particle in the next generation of all living creatures.

5. Reducing the maintenance cost on air conditioning system by keeping the service of it in the standard range.
   When the unit runs based on the frequency, the coupled electromotor's speed is the most in the last throttle of locomotive. Subsequently, the compressor will rotate under the stress. There are two risks that increase the maintenance costs:
   - Reaching the saturation level of electromotor's armature core. It increases the heat, which can cause melting in windings.
   - Lack of lubrication in compressor due to high rotation speed. It increases the friction between cylinder and pistons rings and cause seizing.

In addition to those 5 items, which were the main goal of this project, the results of road test and yard analysis proves that the level of satisfaction of locomotive operators have incredibly raised.

If we multiply the above-mentioned advantages by the total quantity of 100 locomotives that our client has in his fleet, you can calculate the amazing saving done from this modification.

In our AFSS what we offered:

- ✓ Frequency-free system that works on voltage and current basis regulated by our exclusively designed drive.
- ✓ Input voltage control and killing the surge of power
- ✓ Input current control
- ✓ Output voltage control
- ✓ Output current (amperage) control
- ✓ Detecting any kind of surge, short and disconnection in the circuit
- ✓ Controlling the locomotive driver cabin temperature and operate the air conditioner unit in the adjusted range of temperature
- ✓ Controlling the ambient temperature and allowing the unit to work in either condition as per setpoints and definitions
- ✓ Controlling all elements of AFSS, self-assessment, automatically and preventing system of working defected.
- ✓ Programmability of AFSS for administrative access

- ✓ Operational temperature adjustability on the system by admin
- ✓ Operational input and output voltage adjustability from the interface for the administrator
- ✓ Interchangeability of the system is the pioneering feature that is considered in this system
- ✓ Keeping control on the locomotive driver cabin temperature is another advantage of AFSS. In the modified system, the administrator can adjust the operational temperature setpoint for the desired values. Or they can use locomotive air conditioner system with the default setpoints.
- ✓ Soft running of electromotor that reduces the risks of power surge.

In the original version of air conditioning system, there is no control on ambient temperature. A/C system cannot shut down automatically or go to hibernate by intelligent control system. On other words, it is either ON or OFF.

Our system has an intelligent control on the operation of the system. When the temperature raises up to the highest adjusted setpoint, the intelligent drive sends the appropriate command to system to turn the cooling system ON.

System will keep running until the ambient temperature of the driver cabin drops down to the previously set temperature.

In return, the system will turn on for the next times when the ambient temperature touches the targeted point.

Our system has been designed with this logic that:

- Air Cooler Unit will not run with the ambient temperature lower than 18 Celsius.
- Heater will not run with the temperature above 18 Celsius.

However, both setpoints are adjustable by the administrator through the interface software designed for Windows PCs or Laptops.

AFSS is equipped with an event logger that keeps control of probable faults by recording these factors:

- Fault date
- Fault time
- Input current
- Input voltage
- Output voltage
- Output current
- Outside temperature
- Driver cabin temperature
- The number of repeats per each fault

If a unique failure repeats certain times -set as per customer demand- the AFSS will assume it as a permanent failure and will stop system of operation permanently until the unit gets diagnosed by the expert.

Should the system of AFSS fails, still the operator of train or maintenance staff have the opportunity to keep air conditioner system in use by disconnecting the AFSS and reconnecting the cables to the original wiring.

V. References

- ❖ Canadian Center for Occupational Health and Safety (CCOHS)
- ❖ Fast Ferry Powering and Propulsors – Nigel Gee and Association Ltd.
- ❖ MAN B&W Diesel Ltd.
- ❖ Alstom AD43C Maintenance Manual
- ❖ Engineering department of World Part Supplier and the data gathered from field studies.