Fuzzy Logic Controlled Diesel Engine Governor

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***Abstract*— Spark-ignition engines have a flow control in the form of a throttle valve that limits the amount of air passing into the engine. More than the required amounts of fuel may enter and get burnt without delivering the power to the wheels. Engine speed depends solely upon the amount of fuel delivered. If the same volume of fuel necessary to cope with severe loads were delivered under no-load conditions, the engine would rev itself to destruction. Consequently, all engines need some sort of speed-limiting governor.**

***Keywords*— Governor, I.C.Engine, Air Fuel mixture, Fuel Injection Valves, Engine control loop**

I. INTRODUCTION

Diesel engine speed is controlled solely by the amount of fuel injected into the engine by the injectors [1]. Because a diesel engine is not self-speed-limiting, it requires not only a means of changing engine speed (throttle control) but also a means of maintaining the desired speed. The governor provides the engine with the feedback mechanism to change speed as needed and to maintain a speed once reached. Governor is designed to maintain a constant engine speed regardless of load variation [2]. Since all governors used on diesel engines control engine speed through the regulation of the quantity of fuel delivered to the cylinders. These governors may be classified as speed-regulating governors. As with the engines they themselves there are many types and variations of governors. The existing governors are hydro-mechanical type.

It bears problems related to accuracy, response time for correction and wear and tear. In this paper, an attempt is made to explore electro-mechanical actuator driven by fuzzy logic controller. The major function of the governor is determined by the application of the engine. In an engine that is required to come up and run at only a single speed regardless of load, the governor is called a constant-speed type governor. If the engine is manually controlled or controlled by an outside device with engine speed being controlled over a range, the governor is called a variable speed type governor. If the engine governor is designed to keep the engine speed above a minimum and below a maximum, then the governor is a speed-limiting type. The second type of governor is the load limiting type. This type limits fuel to ensure that the engine is not loaded above a specified limit.

II. SPEED LIMITING GOVERNOR

The Diesel Engine governed by Speed Limiting Governor continuously monitors and controls the engine RPM with respect to the set RPM. It has a feedback from the rotating shaft of the engine [3]. Maximum and minimum limits of engine RPM are set and fixed at the fuzzy logic controller. This is the reference for the controller to operate the engine at a particular speed. This type of control loop is applicable in Diesel Generator sets. At all loads the RPM of the engine needs to be operated constant. Here load varies from 0% to 100%. The governor for these conditions maintains the RPM by varying the throttle. During 0% of load the throttle lies in idling and as load varies up to 100% the throttle is pulled to maximum position.

III. LOAD LIMITING GOVERNOR

The Diesel Engine governed by Load Limiting Governor continuously monitors and controls the engine RPM with respect to the manual RPM request. It has a feedback from the rotating shaft of the engine. RPM is selected manually and fed at the fuzzy logic controller. This is the reference for the controller to operate the engine at a selected speed. This type of control loop is applicable in Diesel vehicles. At any speed requests the RPM of the engine needs to be changed. Here speed varies from 0% to 100%. The governor for these conditions varies the RPM by varying the throttle. During 0% of speed request the throttle lies in idling and as speed request varies up to 100% the throttle is pulled to maximum position.

IV. DIESEL ENGINE GOVERNOR APPROACH

The present paper is an attempt to implement fuzzy Logic in governing the Engine throttle to result out a unique performance achieving a smooth and fast control over the diesel engine.

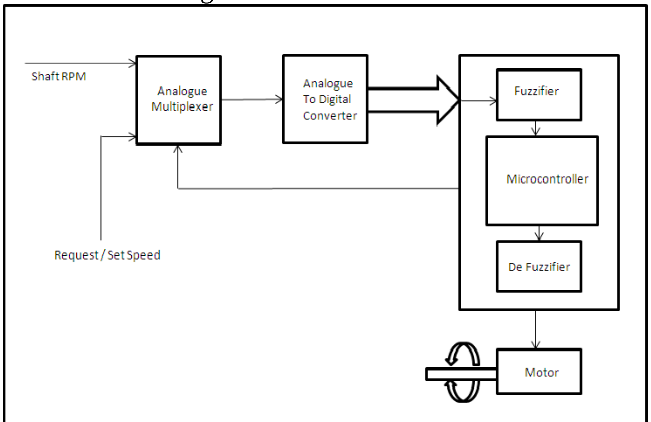


Fig.1 Block diagram of Diesel Engine Governor Controller

Fig.1 illustrates the block diagram of the governor. Analogue Multiplexer is employed to select the analogue data from the “Request/ Set Point” and “Shaft RPM”. A select line running from the controller functions to select the two input lines by the microcontroller. Selected analogue data is converted to digital data using an ADC. The converted digital data is subjected to fuzzification. The rule base in the fuzzifier commands the microcontroller with set of decisions. The decisions depend on the request RPM and the feedback RPM from the shaft. Basic function is to position the throttle through motor at a particular position. This action goes in response to the shaft RPM gradually. This is required since the performance of the engine depends on various factors. When used in vehicle, the engine response depends on road conditions, terrine conditions, loads and on the age and health of the engine. All these factors are read on the shaft RPM of the engine. It reflects in the response time to attain requested RPM while accelerating from a lower RPM to Higher RPM. The acceleration or declaration runs freak free, jerk free and never undergoes sudden displacements. The movement of the throttle takes place smooth along the response of the shaft speed. These decisions are Defuzzified and handed over to the external world that is to a motor to actuate the throttle mechanically. Motor operates in forward and reverse directions depending on the commands it receives. This is in turn is coupled to the throttle of the engine. The positioning of throttle and maintaining of the position is possible through a screw rod coupling between the motor shaft and the throttle lever. Motor operates to change the position of throttle and later stays idle till the next command.

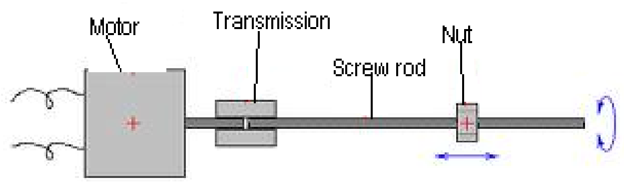


Fig.2. Motorised screw rod mechanism

Fig.2 indicates the Motor coupling and the mechanism to drive the throttle. Transmission coupling is mounted on the shaft and the screw rod which drives rotates the screw rod in forward or reverse directions. Motor is mounted on a fixed base with a reference [4][5]. The nut mounted on the screw rod is hooked to the lever of the throttle. When the motor is energised starts rotating the screw rod and in turn swipes the nut in a particular direction. This action is illustrated in Fig.2 in arrow marks.

V. APPLICATIONS

This paper aims at two applications of the Diesel Engine Governor. One is for Diesel vehicle and the other is for Diesel Generator set. Governing of the engine in both the applications is similar with respect to electromechanical activation of the throttle. The difference is observed in the feedback and the parameters considered for altering the throttle.

A. Diesel Vehicle:

Vehicle as such is subjected to undergo all terrine conditions, different climatic conditions and frequent variation in loads and speeds. And these factors directly make a cause to the performance of the engine. For this ultimately the driver tries to counter them by altering the accelerator, gear, clutch and the breaks. This causes uncertain performance and leads to wear and tear of the engine. Very particularly, the driver is prone to press the accelerator beyond the required level were more than required fuel is pumped into the engine resulting in burning in waste. This results in loss of efficiency. All these variables are considered to alter the throttle position. First of all, reading of accelerator pedal which is called as “Request Speed” in this paper and Shaft RPM are the prime parameters to decide the position of the throttle. Depending on the request the throttle will be varied, and a constant monitoring is made on the shaft RPM. When there is any change in the shaft RPM because of any of the conditions, immediately the throttle will be actuated in a direction to compensate the change. This action takes place gradually taking response from the shaft RPM. The fuzzy logic plays a vital role in deciding the amount of opening of the throttle and at what condition. So, an exclusive logic is required to handle all these situations. An assembly language for AT89C52 is implemented. Programs written for this application is unique and not applicable for the Diesel Generator set Governor.

B. Diesel Generator Set:

Diesel Generator as such is subjected to undergo only frequent variation in loads. The engine is fixed on a base plate were it never undergoes any physical vibrations. Very particularly, the load demand presses the accelerator beyond the required level were more than required fuel is pumped into the engine resulting in burning in waste. This results in loss of efficiency. Counter to these variations can be achieved by altering the throttle. This needs to be considered to alter the throttle position. First of all, reading of pre-set value which is called as “Request Speed” in this paper and Shaft RPM are the prime parameters to decide the position of the throttle. Depending on the request the throttle is varied, and a constant monitoring is made on the shaft RPM. When there is any change in the shaft RPM because of load variation, immediately the throttle is actuated in a direction to compensate the change [4][5]. This action takes place gradually taking response from the shaft RPM. The fuzzy logic plays a vital role in deciding the amount of opening of the throttle and at what condition [6]. So, an exclusive logic is required to handle all these situations. An assembly language for AT89C52 is implemented. Programs written for this application is unique and not applicable for the Diesel Vehicle Governor.

Fuzzyfication and Defuzzification

RPM of the shaft is read and calculated for varying the Governor Voltage. The engine RPM is governed operating the throttle with derived governor voltage. This is applied referring to the peddle position.

Peddle Position
RPM

SS – Small
SR – Small RPM

MS – Medium
MR – Medium RPM

LS – Large
LR – Large RPM

{SS, MS, LS}
{SR, MR, LR}

Governor Voltage:

VS – Very Small

S – Small

M – Medium

L – Large

VL – Very Large

{VS, S, M, L, VL}

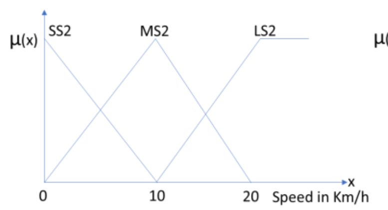
Define range of Peddle Position and RPM, Membership Function of the input and output variables. We use Triangular Membership Functions.

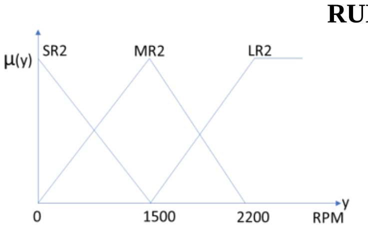
Range for Speed (0 to 100):
Range for RPM (0 to 3000):

SS: 0 to 50
SR: 0 to 1500

MS: 0 to 100
MR: 0 to 3000

LS: 50 to 100
LR: 1500 to 3000





Peddle Position

$\mu_{SS}(x) = 50 – x/50 – 0$

$\mu_{MS}(x) = x – 0/50 – 0 \quad || \quad \mu_{MS}(x) = 100 – x/100 – 50$

$\mu_{LS}(x) = x – 50/100 – 50$

RPM

$\mu_{SR}(y) = 1500 – y/1500 – 0$

$\mu_{MR}(y) = y – 0/1500 – 0 \;,\; \mu_{MR}(y) = 30000 – y/3000 – 1500$

$\mu_{LR}(y) = y – 1500/3000 – 1500$

Membership function for Governor Voltage:

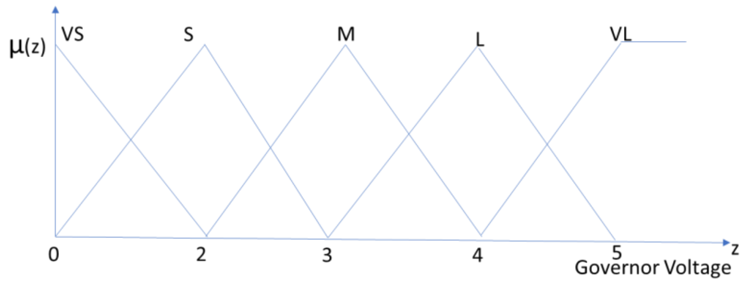
VS: 0 to 2

S: 0 to 3

M: 2 to 4

L: 3 to 5

VL: 4 to 5



$\mu_{VS}(z) = 2 – z/2 – 0$

$\mu_{S}(z) = z – 0/2 – 0 \;,\; \mu_{S}(z) = 3 – z/3 – 2$

$\mu_{M}(z) = z – 2/3 – 2 \;,\; \mu_{M}(z) = 4 – z/4 – 3$

$\mu_{L}(z) = z – 3/4 – 3 \;,\; \mu_{L}(z) = 5 – z/5 – 4$

$\mu_{VL}(z) = z – 4/5 – 4$

RULE BASE FOR GOVERNER VOLTAGE:

PEDDLE POSITION \ RPM	SR	MR	LR
SS	VL	S	VS
MS	VL	M	VS
LS	VL	L	VS

EXAMPLE:

Taking example of a condition were peddle is pressed to 25% and the RPM of the engine is already at 1100 RPM

Peddle Position (x) = 25 and RPM (y) = 1100

(X) = 25 , (y) = 1100

SPEED:

1. $\mu_{SS}(x) = 50 – x/50 – 0$

   $\mu_{SS}(25) = 50 – 25/50 – 0$
   $= 0.5$
2. $\mu_{MS}(x) = x – 0/50 – 0$, $\mu_{MS}(x) = 100 – x/100 – 50$

   $\mu_{MS}(25) = 25 – 0/50 – 0$, $\mu_{MS}(25) = 100 – 25/100 – 50$
   $= 0.5$, $= 1.5$
3. $\mu_{LS}(x) = x – 50/100 – 50$

   $\mu_{LS}(25) = 25 – 50/100 – 50$
   $= -0.5$

RPM:

1. $\mu_{SR}(y) = 1500 – y/1500 – 0$

   $\mu_{SR}(1100) = 1500 – 1100/1500 – 0$
   $= 0.266$
2. $\mu_{MR}(y) = y – 0/1500 – 0$, $\mu_{MR}(y) = 3000 – y/300 – 1500$

   $\mu_{MR}(1100) = 1100 – 0/1500 – 0$, $\mu_{MR}(1100) = 3000 – 1100/3000 – 1500$
   $= 0.733$ $= 1.26$
3. $\mu_{LR}(y) = y – 1500/3000 – 1500$

   $\mu_{LR}(1100) = 1100 – 1500/3000 – 1500$
   $= -0.26$

STRENGTH:

Strength of Rule 1 SS, SR

S1 = Min ($\mu_{SS,}$ μ_{SR})
= Min (0.5, 0.266)
= 0.266

Strength of Rule 2 SS, MR

S2 = Min (μ_{SS} , μ_{MR})
= Min (0.5 , 0.733)
= 0.5

S3 = Min (μ_{MS} , μ_{MR})
= Min (0.5 , 0.733)
= 0.5

S4 = Min (μ_{MS} , μ_{SR})
= Min (0.5 , 0.266)
= 0.266

Maximum Strength = Max (S1 , S2 , S3 , S4)
= Max (0.266 , 0.5 , 0.5 , 0.266)
= 0.5

1. $\mu_{VS2}(z) = 2 – z/2 – 0$

   $\mu_{VS2}(0.5) = 2 – 0.5/2 – 0$
   $= 0.75$

2. $\mu_{S2}(z) = z – 0/2 – 0$, $\mu_{S2}(z) = 3 – z/3 – 2$
   $\mu_{S2}(0.5) = 0.5 – 0/2 – 0$, $\mu_{S2}(0.5) = 3 – 0.5/3 – 2$
   $= 0.25$, $= 2.5$

3. $\mu_{M2}(z) = z – 2/3 – 2$, $\mu_{M2}(z) = 4 – z/4 – 3$
   $\mu_{M2}(0.5) = 0.5 – 2/3 – 2$, $\mu_{M2}(0.5) = 4 – 0.5/4 – 3$
   $= -1.5$, $= 3.5$

4. $\mu_{L2}(z) = z – 3/4 – 3$, $\mu_{L2}(z) = 5 – z/5 – 4$
   $\mu_{L2}(0.5) = 0.5 – 3/4 – 3$, $\mu_{L2}(0.5) = 5 – 0.5/5 – 4$
   $= -2.5$, $= 4.5$

5. $\mu_{VL2}(z) = z – 4/5 – 4$
   $\mu_{VL2}(0.5) = 0.5 – 4/5 – 4$
   $= 3.5$

3.5 Volts is the governor voltage.

VI. PERFOMANCE CHARECTERISTICS

Fig.3 and Fig.4 are the performance characteristics of the Diesel Generator Sets with Centrifugal Governor and Fuzzy Logic Governor respectively.

From Fig.4 performance of Centrifugal governor can be observed that during there is sudden loading on the engine, there is a dip in rpm of engine and takes some time to recover. Over that there is an overshoot and then it settles within the speed band. Similarly, when load is removed, again overshoot is observed for a period and then settles to rpm band.

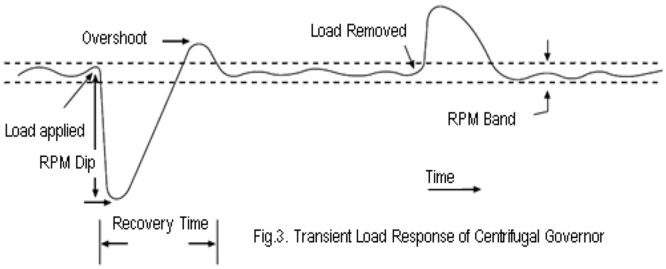


Fig.3. Transient Load Response of Centrifugal Governor

From Fig.4 it is observed that dips and overshoots do not occur in Fuzzy logic Governor. This establishes a smooth run of the engine and a tight regulation in the Generator output. Similar performance can be expected from the automobile also.

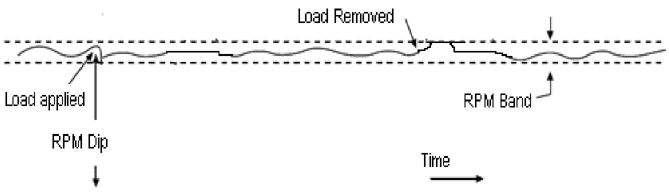


Fig.4. Transient Load Response of Fuzzy Logic Governor

VII.CONCLUSION

This approach is most recommended in both Diesel engine vehicles and the Diesel Generator sets as this continuously monitors and tracks the performance of the engine to operate efficiently. The load regulation is tight from no load condition to the full load condition. When it comes to the application of automobile this governor gives a smooth pull, fast take off and counters unnecessary burning of fuel.

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