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Editorial

Artificial Intelligence in Electrical Engineering

Artificial Intelligence (AI) broadly refers to any human-like behavior displayed by a machine or system. The term "artificial intelligence" describes a wide variety of systems built to imitate how a human mind makes decisions and solves problems. For decades, researchers and engineers have explored how different types of AI can be applied to electrical systems.

Recent progress in areas like machine learning (ML) and AI have affected almost every industry and area of scientific research, including engineering. Electrical engineers contribute to the design and development of new generation equipment. Many of the most promising achievements at the juncture of AI and electrical engineering have focused on power systems; for example systems capable of identifying malfunctions in transmission and distribution infrastructure or forecast how weather conditions will affect solar generation or manage scheduling. Other AI applications include implementing expert systems that reduce the workload of human operators in power plants and also fault detection, routine maintenance, data processing, training, and scheduling of generation.

The use of Expert systems, fuzzy logic control systems, machine learning , Artificial neural networks and deep learning help to solve many challenges faced by Electrical engineers today and also learning and implementing the latest engineering applications of artificial intelligence provide a path for career advancement on the cutting edge of the field.

Dr M. Krishnakumar

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Code of Ethics

- *Thou shalt maintain thy integrity under all circumstances.*
- *Thou shalt incessantly work for the advancement of the professional knowledge.*
- *Thou shalt not give an incorrect professional opinion*
- *Remember Thou art a member of a team and the achievement of the team is thy own success.*
- *Thou shalt not malign thy co-professionalists.*
- *Thou shalt strive for the advancement and dignity of thy juniors in the profession.*
- *Thou shalt strive for the welfare of the community.*
- *Thou shalt enlighten the community with the correct aspect of Engineering/Technological activities.*
- *Thou shalt endeavour to develop a dignified status in the society.*
- *Thou shalt strive by conduct and character to be a worthy citizen of the Motherland.*

Informative Article

VECTOR GROUP OF THREE PHASE TRANSFORMERS

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Substation Subdivision Vatakara

1.Introduction

The vector group notation is the IEC method of categorizing the winding configuration of three phase transformers. As far as three phase power transformers are concerned, there exists a variety of combinations of winding connections having different phase displacements between primary and secondary voltages.

The vector group symbol or connection symbol is the conventional notation indicating the connections of High Voltage(HV),Intermediate Voltage(IV) if any, and LV windings and their relative phase displacements as a combination of letters and clock hour figures. The letter symbol for different windings is expressed in the descending order of rated voltage.

2.Vector Group Designation

In the vector group notation, the symbols are configured in the following way

First symbol- EnglishCapital letter denoting HV winding connection.
Second symbol - English Small letter denoting LV winding connection.
Third symbol- Numberdenoting phase displacement as clock hour number

Winding connection Designations
For HV winding, the Capital letters being used as first symbol are
D- For Delta connection
Y- For Star connection
Z- For Zigzag connection

If neutral is brought out**YN** or **ZN** is used as first symbolsfor star or zigzag connection respectively.

- For IV/LV winding, the small letters being used as second symbol are

d- For Delta connection

y- For Star connection
z- For Zigzag connection

If neutral is brought out for star or zigzag connection, **yn** or **zn** is used as second symbol.

Phase Displacement Designations

The phase rotation is always taken as anticlockwise which is the international convention.

- The *HV line to neutral voltage phasor* is made to coincide with the '*Minute Hand'* of the clock and is set *stationary in the* 12^O *clock* position. This is set as reference.
- The *LV line to neutral voltage phasor* is indicated by the '*Hour Hand'* of the clock. The Hour hand indicates *the phase displacement angle as clock hour number*.

Since there are 12 hours on a clock and a circle consists of 360 degrees, each hour represents 30^0. Thus clock hour 1= 30^0, 2= 60^0, 6= 180^0,………..11= 330^0 and 12= 360^0. Because rotation is anticlockwisethe clock hour numbersand the corresponding phasor displacements for typical cases will be as follows
Clock 12= $^-0^0$- ie LV is in phase with HV
Clock 1= $^-30^0$- ie LV lags HV by 30 degrees
Clock 6= $^-180^0$ ie LV lags HV by 180.degrees
Clock 11 = $^-330^0$ or $^+30^{0\,-}$ ie LV leads HV by 30 degrees

When HV and/or LV to LV windings are delta connected the *imaginary neutral point* given by the centroid of the voltage triangle is to be determined in order to obtain the line to neutral voltage phasor.

The clock hour figures corresponding to the phase displacements of 0, $^-30$, 180 and $^+30$ degrees for two winding transformers are shown in the Figure-1

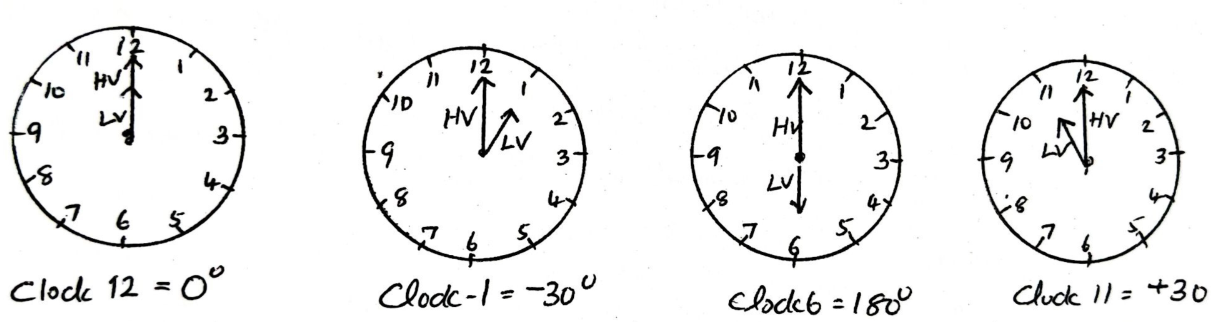

Fig-1 Clock hour figuresfor 0, $^-30$, 180 and $^+30$ phase angles of LV phasor

3.Vector Groups of Two Winding Transformers

Majority of power transformers used in power transmission and distribution networks are of two windings type. The vector group notation or connection symbols of two winding transformers with Star-Star, Star-Delta, Star-Zigzag, Delta-Delta, Delta-Star and Delta-Zigzag connections for various phase displacements are shown in the Table-1

The table shows 26 numbers of connection. Out of these 26 connections, the IS-2026(part 1)-2011 describes the connection with clock hour numbers 0,1,5,6 and 11 as common connections and the connections with clock hour numbers 2,4,7,8 and 10 as additional connections. Hence there exists 15 numbers of common connections and 11 numbers of additional connections.

Phase Displacements (Degrees)	***Clock hour number***	***Vector Group/Connection Symbol***		
0	0	Yy0	Dd0	Dz0
-30	1	Yd1	Dy1	Yz1
-60	2		Dd2	Dz2
-120	4		Dd4	Dz4
-150	5	Yd5	Dy5	Yz5
-180	6	Yy6	Dd6	Dz6
-210/+150	7	Yd7	Dy7	Dz7
-240/+120	8		Dd8	Dz8
-300/+60	10		Dd10	Dz10
-330/+30	11		Dy11	Yz11

Table-1Three phase transformer Vector Groups for various phase displacements

In practice for star or zigzag connection , the neutral will be brought out. Hence the winding designation always will be **YN** or **yn** for star winding and **ZN** or **zn**for zigzag winding.

4.Most Common Vector Groups

Vector group notations of some of the most widely used two winding transformer connections by power utilitiesare given below.

1. **YNyn0**- HV Star & LV Star with neutrals both that brought out and LV voltage is in phase with HV. This connection is used in EHT substations as step down transformers with voltage ratio 110/11kV, 66/11kV, 33/11kV,etc .The Star-Star transformer is economical as the usage of star connection in both HV and LV windings reduces insulation requirements.

2. **YNd1**- HV Star with neutral brought out, LV Delta with -30degree phase displacement. This connection is widely used for Generator Transformers(GT) which are step up transformers with voltage ratio 11/110kV or 11/220kV etc.. Usage of star connection in HV side reduces insulation cost and the delta connection deals the harmonics.For GTs **YNd11** is also used in some power stations

3. **Dyn11**- HV Delta, LV Star with neutral brought out, having LV voltage phasor leading by 30^0 . This connection is widely used for distribution transformers which are step down transformers having voltage ratio 11/0.415 kV. Delta connection at primary side deals the harmonics problems and necessitates only three conductors for primary distribution side. Star with neutral at secondary side facilitates feeding both single and thee phase consumers.

The connection diagrams and the corresponding phasordiagrams of above three connections are given in Fig-2a,2b and 2c respectively.

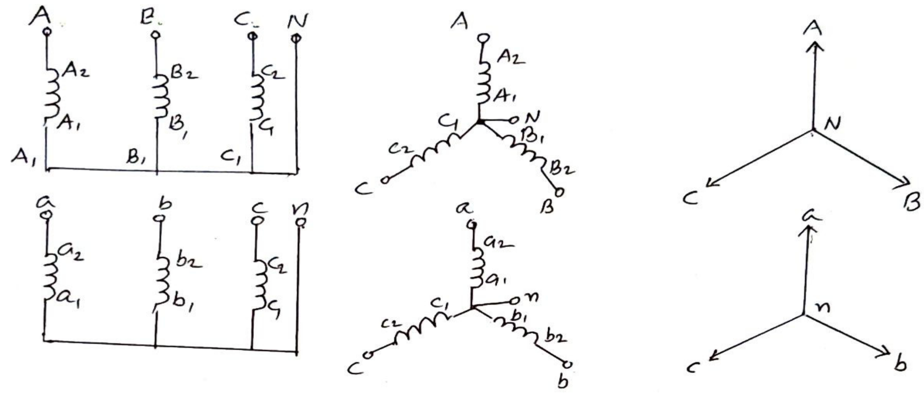

Fig.2a-Star-Star (YNyn0) Connection and phasor diagram

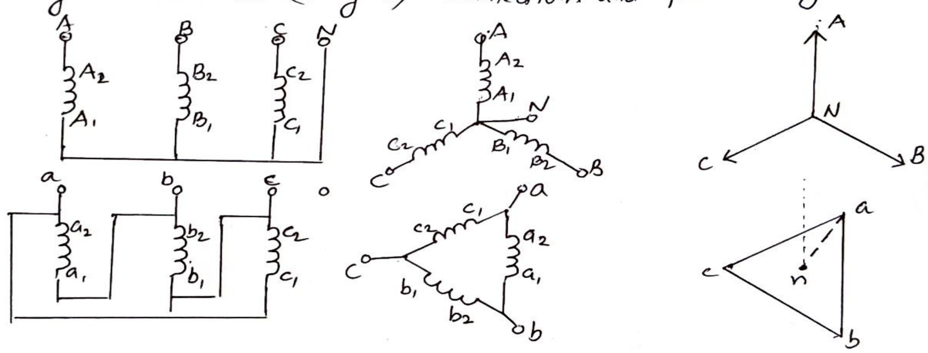

Fig.2b-Star-Delta (YNd1) Connection and phasor diagram

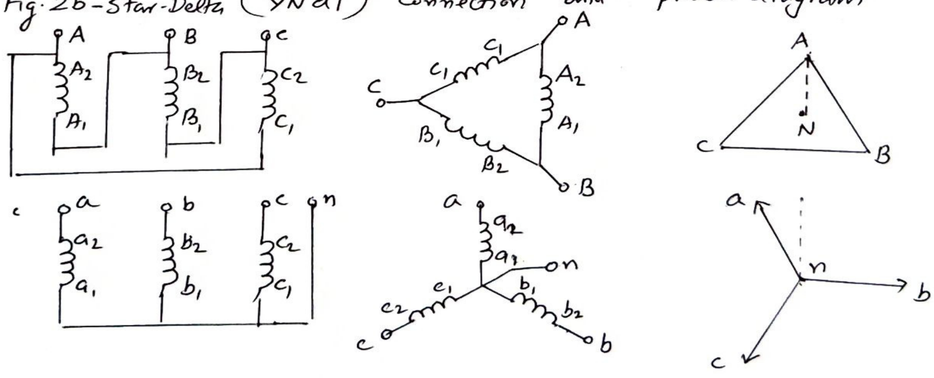

Fig.2c-Delta-Star (Dyn11) Connection and phasor diagram

Reason for using YNd1, YNyn0 and Dyn11 vector groups

In a power system ,thecommonly used vector groups used for Generator Transformer(GT),Inter Connecting Transformers(ICT) and the distribution transformers(DT) are***YNd1, YNyn0/YNa0***

and Dyn11respectively.The reason for using such a combination is to keep the phase angle voltage at consumerend at zero value. At generation side ,*Yd1 connection introduces phase lag of 30 degree* and at intermediate transmission stages this phase angle is unchanged by using Yy0 or Ya0 connections .By using *Dy11 at distribution side, a 30 degree phase lead* is introduced so that phase lag introduced at generation side is nullified.

5.Vector Group of Multi winding Transformers

In Multi winding transformers the letter symbols for different windings are noted in the descending order of rated voltage. The symbol of Intermediate Voltage and Low Voltage winding is immediately followed by the clock numbers for each winding showing respective phase displacements.

Consider a Three winding transformer with voltage ratio 220/66/11kV .The HV & IV are star connected with neutral brought out having zero phase shift. LV is deltaconnected with phase lead 30^0. Here the vector group symbol is **YNyn0d11.**The connection diagram and the corresponding phasordiagramof this connection is given in Fig-3

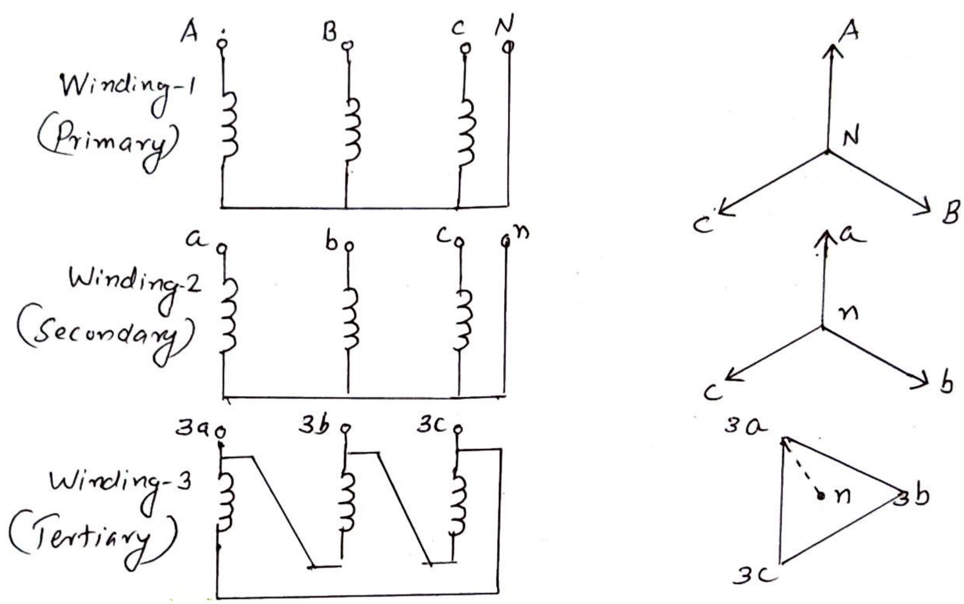

Fig.3-Multiwinding Transformer (YNynd11) Connection and phasor diagram

6.Vector Group of Auto Transformers

Three phase auto transformers consists single winding per phase, which are normally connected in Star with the neutral brought out. So the first symbols will be **YN**. Since auto transformers consists no separate LV winding, the symbol for LV winding is replaced by the letter **'a'** followed by the phase shift clock number. Hence for a star connected step down type auto transformer with neutral brought out and having zero phase shift of LV voltage, the vector group symbol is **YNa0.**The connection diagram and the corresponding phasordiagram of this connection is given in Fig-4.

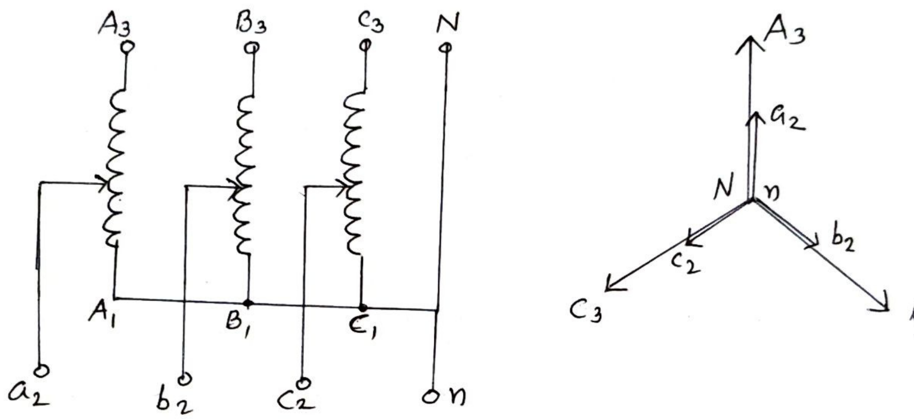

Fig-4 - 3 phase Auto transformer (YNa0) connection and phasor diagram.

If this auto transformer consists a tertiary winding delta connected with $^+$30 degree phase shift,the vector group symbol will be**YNa0d11**. This transformer connection is widely used in major EHT Substations as inter connecting transformers of 400/220kV or 220/110kV voltage ratios.

7.Vector Group Classification and its Importance

The IS-2026(Part IV)- 1977 gives 26 sets of connections of different configurations of YY,YD,YZ, DD, DY and DZ. The displacement of the LV winding vector varies from zero to -330 degree in steps of 30 degrees depending on the method of connection.

Hardly any power system adopts such a large variety of connections, *The commonly used transformer connections have the phase displacement of 0, -180, -30 and +30 degrees* *corresponding to clock hour number of 0,6,1 and 11 respectively*. Thus the three phase two winding transformers can be divided into *four main categories of vector groups*as shown in the following Table-2.

Group No.	***Phase displacement (degrees)***	***Clock hour no.***	***Transformer connections/Vector groups***
I	0	0	Yy0, Dd0, Dz0
II	180	6	Yy6, Dd6, Dz6
III	-30	1	Yd1, Dy1, Yz1
IV	+30	11	Yd11, Dy11, Yz11

The Minus sign indicates LV phasor lags HV phasor and plus indicates LV phasor leads HV phasor by the respective phase angle.

The Vector group symbol is usually provided by the manufacturer along with connection diagram in the name plate of the transformer. Knowledge of vector group is very important before connecting two or more transformers in parallel, The following observations can be made in this regard.

1. Three phase transformers having the same vector group number can be operated in parallel.

2.Three phase transformer belonging to Group III can be operated in parallel with those under Group IV by interchanging any two external HV connections to the supply busbars and also the corresponding two external LV connections to the load busbars. Eg.**Dyn1**transformer can be changed to **Dyn11** by doing change in external connections on both sides.

3.Transformer belonging in Group II can be operated in parallel with those in Group I if the internal connections of one of the transformer are suitably changed. Eg.**Ynyn6** transformer can be changed to **YNyn1** by changing the neutral formed winding ends to line terminals and line terminal winding ends to neutral connection.

<u>8.Vector Group Change by Connection Changing</u>

Case 1- Changing external connection on one side.

The conventional method of connecting the phase is connecting R on terminal A, Y on B and B on C. However the phase displacement can be changed in secondary side by connecting primary side external terminals in unconventional fashion, ie R on B, Y on C and B on A etc…..

Group I (0^o)- By changing external connection on one side, an internal connected **Dd0** transformer can be changed to **Dd4**(-120^o) or **Dd8**($+120^o$)

Group II (180^o)- By changing external connections on one side, a **Dd6** transformer can be changed to **Dd2**(-60) or **Dd10**(+60)

Group III (-30) - By changing external connection on one side, a **Dyn1** transformer can be changed to **Dyn5**(-150) or **Dyn9**(+90)

Group IV (+30) – By changing external connection on one side, **Dyn11** transformer can be changed **Dyn7**(+150) or **Dyn3**(-90).

Case 2- Changing external connections on both sides,

By Changing external connections on both sides,aGroup III or Group IV transformer can be changed to any of these two groups, thus **Dyn1** transformer can be changed to **Dyn11** or **Dyn3** or **Dyn5** or **Dyn9**. This is applicable for Star delta transformer also.

Case 3- Changing internal connections

By Changing internal connections, a star/star or delta/delta transformer can be changed from Group I to Group II and vice versa.

9.Conclusion

Three phase transformers can have variety of combinations of winding connections having different phase displacements between primary and secondary. Vector groupnotation indicates the type of connections of HVand LV windings and their relative phase displacements of voltages as a combination of letters and clock hour figures.Knowledge of vector group is very important before connecting two or more transformers in parallel.

As per IS-2026(Part IV) about 26 Nos of connections with different vector group are possible.However in practice a few are used by the power utilities.Thecommonly used three phase two winding transformer connections having the secondary phase displacement of 0, -180, -30 and +30 degrees(clock hour number of 0,6,1 and 11)can be classified into four main groupsof vector groups namely-GROUP-I,II,III and IV respectively.

In some cases, the existing vector group of a transformercan be changed by changing external connection on one side or by changing external connections on both sides or changing internal connections.But this not usually done in practice.

10.References

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3.Wikipedia-Transformer Vector Groups
4.The Indian Standard on Power Transformers-2026(Part IV)- 1977

Report Article

SOLAR POWER DRIVEN AGRIBOT

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ABSTRACT: The goal of this proposed method is to create an agricultural robot that will assist people in their daily lives by doing tasks such as digging up soil, planting seeds, spraying pesticide, cutting grass, ploughing, and detecting obstructions. The methods that were utilised in prior projects were both difficult and costly to implement. This AGRIBOT operates on renewable energy, specifically solar energy obtained from a solar panel-powered battery. It also includes a visual obstacle detector and a Bluetooth module, which is connected to a Bluetooth terminal application, which allows it to be easily controlled and the AGRIBOT to be given instructions for the operations to be carried out by the AGRIBOT. Because it is a low-cost AGRIBOT that is simple to use and does not need the farmer to travel to the field directly, it assists farmers in facilitating the ease of work by minimising human effort, saving time, and conserving resources. Farming may be done with relative ease in every climatic condition, regardless of the time of day or night. When compared to other robots, this AGRIBOT is very advantageous since it has a multitasking functioning system as well as sophisticated methods for smart farming.

1. INTRODUCTION

Based on an AGRIBOT, which does various chores for the farmer while saving them time, energy, and money while also maintaining a record of what has been done, this study work has been carried out. Seed planting, ploughing, spraying pesticides, mowing grass, and identifying barriers are some of the multiple tasks that the AGRIBOT is capable of doing. For the AGRIBOT, 6 motors are required, with 2 motors being used for controlling directions and the remaining motors being used for seed sowing, grass cutting, spraying and ploughing. The motors must all be connected to the micro controller and integrated circuit, and a proximity sensor must also be attached to the setup in order for it to detect obstacles. All appliances are wired into the solar panel, which charges the battery, stores that energy, and then gives electricity to the whole circuit. All of them are high-security applications that run on solar power and are completely safe to use and handle.

The AGRIBOT is managed by the farmers, who must send commands to the AGRIBOT using the Bluetooth HC-05 programme on their android mobile phone, which is simple to use and allows them to easily access the AGRIBOT. When a command is issued, it recognises the command and proceeds to carry out the action. The use of solar panels in agricultural fields reduces water wastage because an excessive and continuous flow of water is not required. It also reduces pollution because the use of fossil fuels is minimised, and it is cost-effective because it is generated directly from the sun, as opposed to other energy sources.

2. LITERATURE SURVEY

[2]Describes the many complicated techniques, including as seed planting, pesticide spraying, and grass cutting, that are used in agricultural production. This robot system is supplied by solar energy, with the solar panel supplying the energy to the robot, which is controlled through Bluetooth or Android, and which sends signals to the robot to enable it to execute the necessary function and move in the desired direction. The major drawback of this technology is that it does not do ploughing operations. [3] These robots are operated without the need of hands and have a quick data input operation. The farmer gets information regarding the robot's performance through Bluetooth. The main disadvantage of this system is that it works in manual mode for the purpose of control. Specifically, in [4] article, the operation was carried out only via the use of an Android application that was only supported by a WLAN network that was comprised of two sensors, the first of which measured the distance to the item and the second of which measured the earth's magnetic field.

The gadget is powered by a battery that is charged by solar energy. The most significant disadvantage is that it only works in one way. According to [5,] the author describes the development of precision farming, which involves the need for farming that is based on electric detecting devices that are cheap in cost and operate on a time-based basis. The system's disadvantage is that the farmer must operate the vehicle on his or her own. It is said in [6] that the initiative is intended to save farmers' time and energy by automating repetitive activities, as well as to improve the amount of crop produced. It is a four-wheeled robot that is controlled by the LPC2148 microcontroller. In this case, the disadvantage is that it is a single-functioning robot that cannot execute several tasks. Although the project is intended to conduct operations like as automated ploughing, seed planting, and fruit picking [7], it also has the capability of being operated manually if necessary.

Another component of this project is a humidity sensor, which measures and transmits the humidity of the surrounding air through SMS to the farmer via the GSM module. When an impediment is identified in this situation, the system is unable to react appropriately. In [8], the article is based on a robot that is comprised of sensors, which is a visual robot with a GPS that assists the robot in navigating to the agricultural field and determining its own position; nevertheless, the paper has a drawback in that it bumps up to 3cm. It can also tell whether or not a seed has been dropped with pinpoint accuracy. In [9], the DTMF technologies are utilised in the project, and the robot is operated via a cell phone from a remote location, where the wetness of the soil and the sawing of seeds are being investigated.

The disadvantage is that it is necessary to use a SIM card to control the robot. In [10], the article describes a low-cost robot that is intended to make precise seed selections by using hardware that includes grabbing, inclination, transforming, and intelligence modules, among other things. The disadvantage is that it only fulfils the function of seed selector. In [11], the paper is meant to identify impediments visually and via the use of sensors, and it is primarily intended to improve the yield of the crop while also reducing the amount of energy used by farmers.

Using the example of better water management, this article demonstrates the positive impact of productiveness and rational use of environmental assets. The management of irrigation water is one of the most common applications of computer systems in agriculture. Because it only operates a water irrigation system, it has the drawback of being limited in its capabilities. This article [13] is primarily concerned with direct current motors (DC motors), which are extensively utilised in industrial applications for variable speed drive systems. GSM, Wi-Fi, Zig-bee, and Bluetooth are all wireless technologies. Bluetooth is used for communication, and the speed control is handled via Bluetooth. The disadvantage is that Bluetooth only controls the motors. [14] The suggested work in agriculture uses low cost technologies such as low data rate, low power consumption, and a wide coverage area, all of which are cheap in cost.

Table 1: Review on Computer Vision

REF. NO	TITLE & YEAR	TECHNOLOGY/TOOLSUSED	MERIT/DEMERIT
[2]	Solar Powered Autonomous Multipurpose Agricultural Robot Using Bluetooth/Android-2019	Bluetooth technology, Solar technology, Android	Ploughing operations can’t be done

[3]	Smart Phone Operated Multipurpose Agricultural Robot-2019	Bluetooth technology, smartphone	Need to control robot manually
[4]	Automated Seed Sowing Agribot using Arduino-2016	WLAN technology	Operates only in one direction
[5]	Agricultural robotics: A streamlined approach to realization autonomous farming-2007	Precision autonomous farming (PAF) & GPS technology	Need to control robot manually
[6]	Precision agriculture robot for seeding function-2016	PFDS & PADS technology	Does not perform multitask
[7]	Automatic ploughing and Seeding Robot-2016	PFDS & PADS technology	Obstacle detection is not possible
[8]	Sensor and vision based autonomous agribot for	DIP, PFDS & PADS technology	The system used was not accurate

3. SOLAR POWER DRIVEN AGRIBOT BLOCK DIAGRAM

3.1 OVERVIEW

This AGRIBOT assists farmers in doing their tasks with more ease and precision. Because it runs on renewable energy sources, its operating costs are very cheap. Farmers may operate it from a distance using a remote control.

3.2 BLOCK DIAGRAM

The AGRIBOT is a multitasking machine that may assist farmers in replacing equipment that operate on fossil fuels such as gasoline, diesel, and other similar fuels. The AGRIBOT is an electrically powered machine that relies on electricity as its primary source of energy to function. In order to keep the battery charged at all times while it is in use, it is equipped with a solar panel. In this type, a 10 watt solar panel is linked to a 12 volt battery, which provides power. A charging circuit connects the solar panel to the battery, allowing it to charge the battery. Although the Arduino Uno open source board with the ATmega328 microcontroller is the central component of this machine, it is not the only component. It is in charge of all of the functions in AGRIBOT. All of the machine's motors are controlled by motor driver modules that are specifically designed to accomplish the duties that AGRIBOT is tasked with. Ploughing, seed planting, crop watering, pesticide spraying, and weed cutting are all tasks that the AGRIBOT can do. The AGRIBOT is operated via the use of a smart phone and an Android application.

This specific model communicates with the outside world through Bluetooth technology. Hc05 is a Bluetooth module that simplifies and automates the process of communicating with others. In addition, it includes an obstacle detecting feature. The presence of an obstruction is sensed by an infrared sensor module, which is mounted in front of the machine. Whenever an impediment is identified, the machine travels backwards until it has cleared the obstruction completely. Additionally, a message is sent to the smart phone. There is also an additional feature known as edge detection, which makes use of two infrared sensor modules, each of which is mounted directly in front of the vehicle's wheels. Whenever it comes across an edge, or if there is no route to follow, this function pauses and travels back until the edge has been cleared. It also sends a text message to the smart phone's recipient.

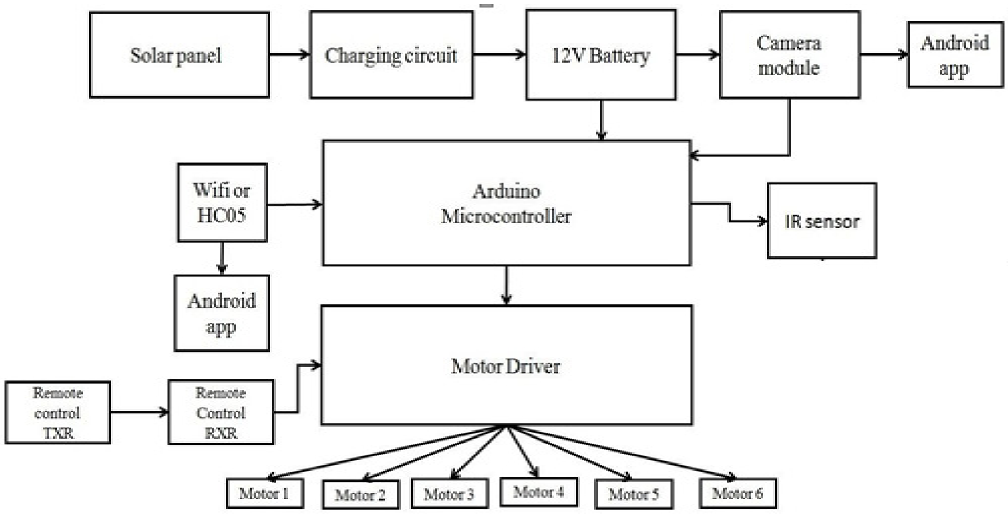


Figure 1: Block Diagram Solar Power Driven AGRIBOT

Two extra components may be added to the AGRIBOT: a camera module and a remote control module, if the user does not want to operate the machine using a smart phone as the primary control device. The advantage of using a camera module is that the user does not have to be in close proximity to the machine while it is operating.

3.3 FRAMEDESIGN

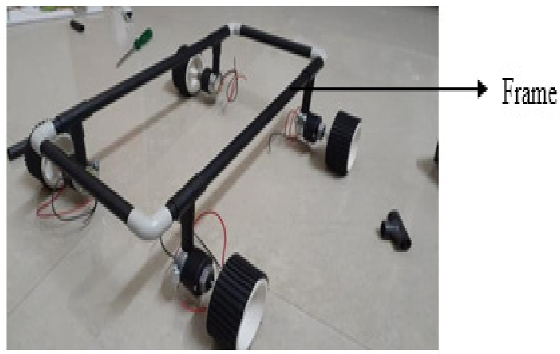


Figure 2: AGRIBOT Frame

PVC pipes of quarter-inch diameter are used to construct the frame of AGRIBOT. A smaller weight and a longer life span are achieved as a result of this design feature. Utilizing PVC pipes saves money and is also a simple task to do successfully.

3.4 EQUIPMENTMOUNT

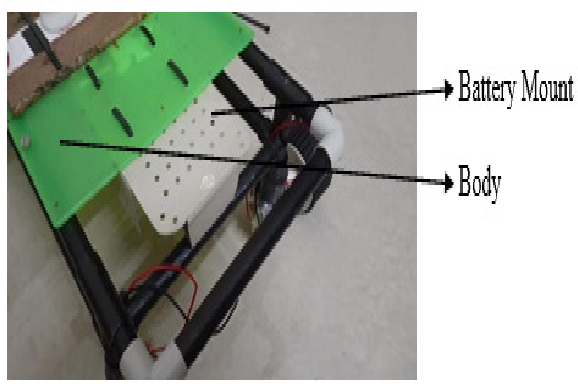


Figure 3: Equipment Mount

The Equipment Mount is a metal frame construction that is used to hold the equipment that is used for ploughing and weed cutting. It is just a salvaged robot chassis with ports for attaching gear motors.

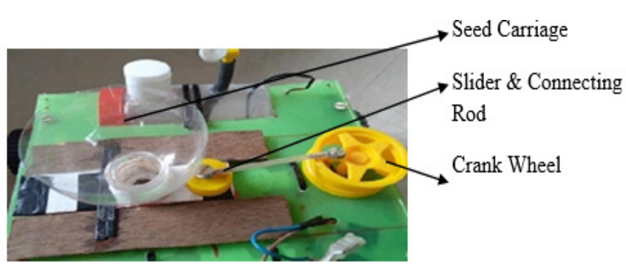


Figure 4: Seed Sowing Assembly

The seed sowing assembly is composed of a plastic bottle, a robot vehicle wheel, a bottle cap, and a pen refill, which serves as the connecting rod between the bottles. The workings of the seed sowing assembly are accomplished via the employment of a crank and piston assembly mechanism. When the slider where the seed carriage is fixed moves back and forth, a hole is created on the body, and when the hole matches the bottom side opening of the seed carriage, the seed is released; when the slider moves back, the hole is closed, and the seed falling through the hole is stopped; and when the slider moves forward, the hole is closed, and the seed falling through the hole is stopped.

3.5 WATER TANKASSEMBLY

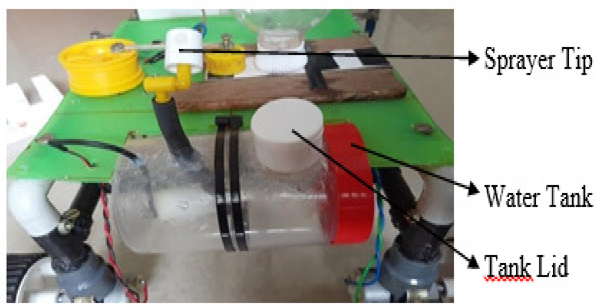


Figure 5: Water Tank Assembly

The water tank assembly is composed of a plastic bottle that has been modified to take on the shape of a water tank. Pumping water is accomplished via the use of a submersible 12v dc pump placed in the water tank. A sprayer tip has also been added for the purpose of spraying. A manual adjustment may be made to the location of the sprayer tip.

3.6 CONTROL MODULE

Figure 6: Control Module

The AGRIBOT's control module is comprised of two dismantled mobile telephone boxes. The control box is where all of the electronic components are housed together. The boxes are stacked one on top of the other to form a stack. This box contains all of the motor driver modules, while the Arduino, Bluetooth Module, and power supply board are located in the box at the top of the stack. In addition, there is a cooling fan located on the side of the bottom box to keep the motor drivers from overheating.

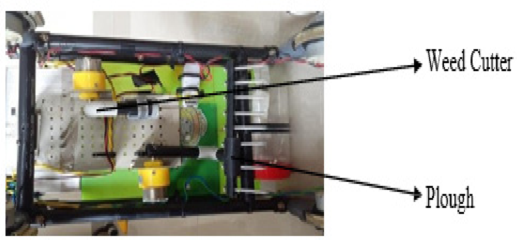
3.7 BATTERYFIXTURE

Figure 7:Battery Fixture

The battery fixture is a top-opening box construction that is used to keep the battery in its proper place. The AGRIBOT is powered by a 12v 7.2 Ah lithium-ion battery. The simple design makes it simple to remove the battery for routine maintenance reasons.

3.8 ROBOT UNDERSIDE PLOUGH ASSEMBLY & WEED CUTTER ASSEMBLY

Figure 8: Robot Underside Plough Assembly & Weed Cutter Assembly



This component includes the plough and weed cutter assemblies, which are located on the bottom of the AGRIBOT tractor. Listed below are the tools and equipment used for ploughing and weed cutting. The plough assembly is made up of two parts: a motor that moves the plough up and down and a plough blade that ploughs the ground. An electric motor for moving the cutter up and down and a motor with a blade for cutting vegetation are both included in the weed cutter assembly.

3.9 SOLAR PANEL AND SENSORS ASSEMBLY

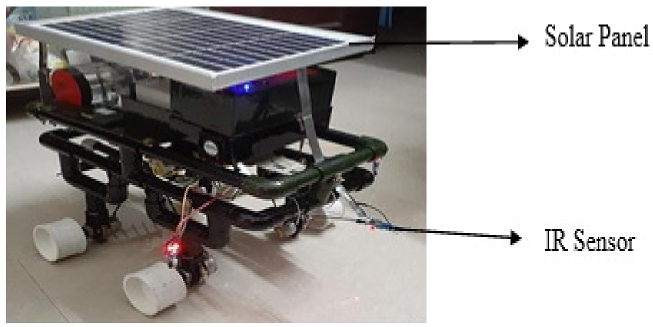


Figure 9: Solar Panel & Sensors Assembly

Using the energy produced by the solar panel, the AGRIBOT battery is kept fully charged all of the time. The AGRIBOT's battery charging is accomplished via the use of a 24V 10W solar panel. The AGRIBOT is capable of detecting barriers and edges, and in order to do so, infrared sensors are used for this purpose. The AGRIBOT's infrared sensors are located in the front, as well as on the front left and right sides of the vehicle.

4. FUTURE SCOPE

The use of robots in agriculture is becoming more common. Many initiatives that may be adopted in the future to provide additional advantages in the contemporary world of smart farming are now being considered. Here are a few examples of what they are:

• Farming may be done on disaster-stricken land, such as tsunami-affected land, where human farming is impossible, and where these AGRIBOTS are very helpful to farmers.

• Drip irrigation may also be accomplished via the use of enhanced technologies and techniques.

• Adding GPS and GSM modules may be even more beneficial since they eliminate the need for constant monitoring, allowing the job to be done around the clock indefinitely. In order to protect farms from animals, electric fence may be installed in the field.

• Cameras may be placed on the AGRIBOT to make it more easy to use as well as to provide additional security.

5. CONCLUSION

It has been determined that the primary goal of this AGRIBOT is to assist farmers in easing their work and increasing their productivity through its multitasking working features such as seeding, sowing, ploughing, spraying pesticides with obstacle detection, and these advanced features overcome the difficulty of farmers in farming their land in any climatic condition, regardless of day or night, as previously stated. It is being started by combining features from all of the hardware components that are being used; all of the modules are being carefully examined and organised in order to provide the greatest possible operation of the unit. These AGRIBOTS are a godsend to today's farmers, allowing them to farm more efficiently and effectively while increasing their yields and profits.

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Research Article

Forecasting Electricity Consumption in Kerala using ARIMA Model

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Abstract:

The demand for electricity in Kerala has been increasing rapidly over the years. Forecasting the consumption pattern is important to the planners to formulate appropriate strategies. In this study, an attempt is made to forecast electricity consumption in domestic , commercial, industrial, HT&EHT and agriculture sectors along with the total electricityusing the Autoregressive integrated moving average (ARIMA) model. The historical data for the period 1990 to 2019 was used for analysis. The accuracy of the models is tested using R^2, RMSE, MAPE values.

Keywords: Electricity consumption, Forecast, ARIMA model

1. Introduction

Electricity has a key rolein the overall development of any nation. Factors like population growth, rising living standards, urbanization, technological developments, industrialization etc. raise its demand. The average daily consumption of the state is around 64 MU.Though Kerala was an electricity surplus statein the past, since 1983 it became an electricity deficient state. The internal generation provides only around 30% of the totalelectricity requirement of the State.The electricity consumption in the state grows with a compound annual growth rate (CAGR) of around 6%. The annual growth rate of electricity usage is relatively high, especially during 2011-12 (10.24%) and 2013-14 (12.05 %) . The total consumption has increased to 22716.77 MU (Million Units) in 2019-20 but decreased to 22413.02 MU in 2020-21. This dip can be attributed to the adjustments made consequent to the COVID-19 pandemic.

Forecasting the future electricity demand is essential for power system planning and control. One of the widely used statistical techniques in forecasting time series data is the Autoregressive integrated moving average (ARIMA) model. The ARIMA model results show thatit performs high prediction accuracy. An ARIMA(p,d,q) model has three parameters, where ‘p’ represents the order of the autoregressive (AR) part, ‘d’ denotes the degree of first differencing (I) involved and ‘q’ denotes the order of the moving average (MA) part.The ARIMA model is used to forecast the electricity demand for the period from 2020 to 2030. The general ARIMA model is given by:

$$\Phi(B)\,(1-B)^{d}y_t = \delta + \theta(B)\epsilon_t$$

where δ is the constant term, ϵ is the white noise, $\Phi(B) = 1-\Phi_1 B-\Phi_2 B^2-\cdots-\Phi_p B^p$ and $\theta(B) = 1+\theta_1 B+\theta_2 B^2+\cdots+\theta_q B^q$

2.Data and methodology

Sector wise historical electricity consumption data was collected for the period 1990 to 2020 from the‘Power System Statistics’ reports published by KSEB in various years. The past and present data to establish the relationship between electricity consumption and period 1990 to 2020 was analysed. Analysis was conducted forthe domestic, commercial, industrial, agriculture and high tension & extra high tension (HT &EHT)sector consumptions and total consumption. The electricity consumption has a significantly upward trend in all sectors.The sector wise consumption pattern during the period from 2010 to 2020 is shown in Fig.1

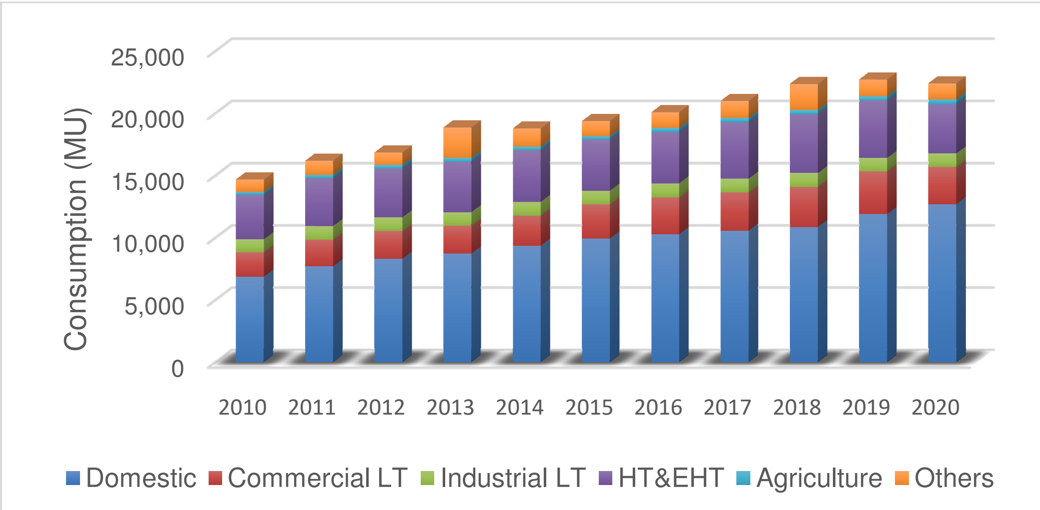

Fig.1 Sector wise consumption

As there is a dip in consumption during 2020, data from 1990 to 2019 was taken to forecastthe demand. The ARIMA (p,d,q) technique is adopted for analysing the time series data. The models with highest R^2 value and lowest Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE) and Mean Absolute Error (MAE) values are identified.ARIMA(1,1,1)model has shownhigh precision and hence selected it for estimatingthe future electricity demand.

3.Results and Discussions

The electricity consumption data for the period from 1990 to 2019 is taken to forecast the consumption up to 2030 using ARIMA model. The data analysis was performed using SPSS statistical software. Table.1depicts the forecasting results obtainedusing ARIMA(1,1,1) model for different sectors.

Table 1:Summary Statistics of sector wise electricity consumption in Kerala

Sector	R^2	RMSE	MAPE	MAE
Domestic	0.989	329.458	4.235	187.942
Commercial	0.970	155.853	8.333	99.039
Industrial	0.980	38.240	4.157	29.064

HT&EHT	0.872	308.580	7.382	189.447
Agriculture	0.504	43.561	11.155	27.734
Total	0.982	759.385	4.703	513.690

A higher R^2 value suggests better accuracy. The R^2value above 0.7 would generally be considered as good. MAPE value below 10 is considered as a very good model where as 10-20 is considered as good. The values obtained are very good for all sectors except for agriculture sector. Table. 2 shows the sector wise demand forecasted for the period from 2020 to 2030. All the sectors show an increasing trend.

Table 2:Sector wise electricity demandforecast (in MU)

Year	Domestic	Commercial	Industrial	HT&EHT	Agriculture	Total
2020	12559.53	3689.85	1097.36	4605.31	345.92	23300.00
2021	13268.02	3973.58	1118.12	4634.32	344.63	23896.30
2022	13976.50	4279.14	1142.30	4686.32	344.34	24493.90
2023	14684.99	4608.19	1167.84	4751.70	344.83	25091.80
2024	15393.47	4962.54	1193.92	4824.85	345.92	25689.60
2025	16101.96	5344.14	1220.23	4902.51	347.50	26287.50
2026	16810.44	5755.09	1246.61	4982.80	349.44	26885.30
2027	17518.92	6197.63	1273.04	5064.61	351.67	27483.20
2028	18227.41	6674.21	1299.48	5147.31	354.14	28081.00
2029	18935.89	7187.43	1325.92	5230.53	356.78	28678.90
2030	19644.38	7740.12	1352.36	5314.05	359.56	29276.70

The total electricity consumption and demand forecast chart is in Fig.2 . It show that the actual consumption and forecast data are very close together.

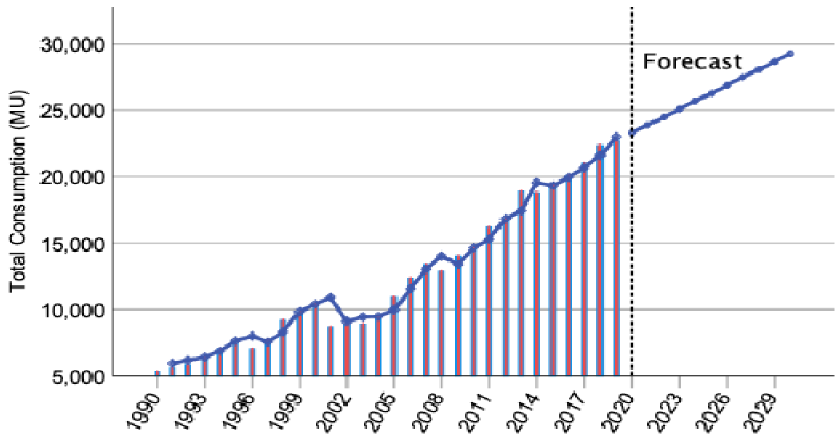

Fig.2 . Actual data Vs forecasted data

Table.3 displays the sector wise actual consumption during 2020,demand forecastedfor 2020 and deviations.

Table 3: Changes in consumption pattern during 2020

Sector	**Consumption in (MU)**			**Annual Growth (%)**	**Deviation from forecast (%)**
	2019 (Actual)	**2020 (Forecast)**	**2020 (Actual)**		
Domestic	11898.13	12559.53	12699.64	6.74	1.12
Commercial	3426.37	3689.85	2982.47	-12.96	-19.17
Industrial	1085.16	1097.36	1086.67	0.14	-0.97
HT&EHT	4615.88	4605.31	3955.32	-14.31	-14.11
Agriculture	348.48	345.92	403.24	15.71	16.57
Total	22716.77	23299.98	22413.02	-1.34	-3.81

The total electricity demand in the year 2020 shows a dip of 1.34 % from the previous year. It is 3.81% less than the forecasteddemand. The commercial and HT &EHT industry demands have dropped significantly. The decline in commercial usage is 12.96 %, and that in HT&EHT usage is 14.31%. But a notable exception is in the domestic usage, which shows an increase of 6.74% during 2020. The actual domestic consumption during 2020 is 1.12% higher than the forecast. These are due to the extraordinary impact of the Covid 19 pandemic and the resulting lockdown measures.The COVID-19 pandemic had hit all societies in the world in full force in 2020.

As per the study, 25.6 % increase in electricity demand is observed from 2020 to 2030. During this period, maximum rise would be in the commercial sector with an increase of 109.77 %.

4. Conclusions

Electricity demand forecasting plays an important role in planning. An appropriate ARIMA model is developed to forecast electricity demand in different sectors up to 2030 from the historical time series data.The forecasted data verified with the historical data and observed that the values are almost close to each other. As the electricity tariff is now under the MultiYear Tariff framework, it is essential to have a correct demand forecast to arrive an appropriate tariff structure. The forecast has shownthat the electricity demand will be around 29,300MU in 2030.The Covid -19 pandemic related restrictions also had profound impacts on electricity demand in different sectors.

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Research Article

Energy Efficient Behaviour in Domestic Environment

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***Abstract*:**

This study aims to seek the most conducive energy efficient and environment-friendly behavioural attributes by surveying a representative sample of household energy consumers in XYZ Residents' Association, located in India, employing multi-grade fuzzy logic and importance-performance (IP) analysis and to extend the results obtained from the study to other areas with similar socio-cultural disposition. Judicious use of energy sources assumes prime importance in attaining energy efficient behaviours and this also helps to achieve environmental protection. This paper proposes to assess how important are the behavioural attributes of energy efficiency and environmental protection in a household setting by collecting responses from energy auditors and home makers, and performing Importance- Performance (IP) analysis to identify the behavioural attributes conducive to energy efficiency and environmental protection. The Energy Efficiency Behavioural (EEB) Index of the residents of XYZ Residents' Association is also assessed employing multi-grade fuzzy method.

Keywords: *Energy Conservation, Efficiency Behaviour, Curtailment Behaviour, Maintenance Behaviour, Multi-grade Fuzzy, Importance- Performance Analysis*

1.Introduction

Energy is a scarce resource available to the mankind and it can be put to different applications. Judicious use of energy and its conservation assume prime importance in life. The energy can be primary energy, which is extracted or tapped directly from nature like solar, wind, tidal, geothermal, biomass etc. (which fall in the category of renewable energy) or fossil-based fuels such as crude oil, natural gas, coal, lignite etc. (which fall under the category of non-renewable energy). Secondary energy sources are mostly Steam and Electricity which are produced by the industrial utilities from primary energy sources. Energy and Environment are closely interrelated as the production of Secondary Energy or utilisation of non-renewable energy sources in industry results in emission of oxides of Carbon, Sulphur, Nitrogen etc. and other flue gases which pollute the environment. The global Primary Energy Consumption for the year 2018 is 13864.9 Million Tonne of Oil Equivalent (MTOE)* and the growth rate per annum as in

2018 is 2.9% & the global carbon dioxide emission for the year 2018 is 33890.8 Million Tonnes of CO2 ($MtCO_2$)

- 1 Tonne of Oil Equivalent (TOE) = 41870 Mega Joules = 11630 kWh = 10^7 kilo Calories

and the growth rate per annum is 2.0% (BP Statistical Review of World Energy, 2019, UK). In terms of final energy consumption in India, industry accounts for 56%, the transportation sector accounts for 17% and the residential and commercial sectors account for 13% (TERI, 2019). As regards climate change, the year 2017 was the fourth warmest year on record, since 1901 (TERI, 2019). Carbon dioxide emission in India stood at 2344.2 $MtCO_2$ in 2017 (TERI, 2019). The energy use in high consuming industries are subjected to audit by qualified and experienced energy auditors and managers and they suggest ways and means to reduce consumption or improve efficiency, which the industry adopts.

In the case of residential consumers, it is not the case and the efficiency of utilisation of energy in domestic sector is far low, which underpins the requirement of this study. Moreover, the number of residential consumers is far more than the industrial houses and the behaviour of the members of the households affect the energy use in the residential sector.

Globally, the growth of primary energy consumption and carbon dioxide emission from the year 2007 to 2018 is tabulated below, in Table 1, as reported in the BP Statistical Review of World Energy, 2019; United Kingdom 68th Edition. Both Primary Energy Consumption and carbon dioxide emission could be reduced by practising energy conservation behaviours by the consumers of energy.

Table 1: Global Growth of Primary Energy Consumption (MTOE) & CO_2Emission

Year	Consumption in MTOE	CO_2 Emission in $MtCO_2$
2008	11705.1	30336.7
2009	11540.3	29719.4
2010	12099.9	31057.9
2011	12403.7	31978.3
2012	12575.5	32316.7
2013	12819.4	32799.9
2014	12939.8	32844.8
2015	13045.6	32804.4
2016	13228.6	32913.5
2017	13474.6	33242.5
2018	13864.9	33890.8

Inculcating energy saving behaviours among the members of the households depends on a variety of factors such as attitudes, values, behaviours, environmental concerns of the individuals, level of awareness of individuals etc. The Consumer Energy Behaviour is complex and it does not follow the traditional theories of decision making (E.R. Frederiks et al, 2015). Though most of the residential consumers are aware of the climate change issues and they are concerned about saving energy to save environment; such concerns do not translate into taking practical decisions entailing in reduction in consumption. Invisible nature of energy, careless attitude towards energy use, lack of trust etc. are serious barriers to efficient energy consumption in the domestic environment (Tang &Bhamra, 2008).

Domestic energy consumption and conservation encompass a wide variety of disciplines like economics, psychology, sociology, technology, consumer behaviour, organisationalbehaviour, environmental studies, costing, pollution control etc. and hence is a truly interdisciplinary topic which offers good scope for research and development and is worth-studying for the benefit of the society, mankind and the future generations to come. Such studies cover national and global interests and are incidental to providing the much needed energy security to the whole world, though the conditions prevalent in the study are applicable for a particular region based on the culture, demography, climatic conditions, life style etc. of the region. This study aims at assessing how important are the various attributes of Energy Efficiency and Environmental Protection and how they are correlated with practices in a domestic environment by collecting responses from energy auditors and managers to assess the importance criteria and home makers in a residents' association in Alappuzha Municipal area who manage their households for the performance levels; using fuzzy logic. Importance- Performance (IP) Analysis is then performed to identify which of the attributes require more careful management to attain the desired levels of Energy Efficient Behaviour as well as maintaining a benign environment and which among the attributes are well taken care of by the representative sample of the population which comprise of 148 residents belonging to the XYZ Residents' Association, located in Alappuzha Municipality of the State of Kerala. The sampling method adopted is snowball sampling.

2. Literature Review

The intensity of energy use in any economy is an indicator of development and per-capita consumption of energy is normally considered as a development index of a country or region. The efficiency of energy use without giving away as waste is another significant area to be addressed to curtail wastages and to improve the effectiveness of the production or conversion processes. From the perspective of a residential consumer, there exist umpteen numbers of peculiarities for energy, as a commodity of use in comparison with other consumer goods and services that are consumed in the domestic environment. Energy is very abstract, its consumption is inconspicuous; compared to other consumer goods and the sources of energy like electricity or gas are really intangible, except that domestic gas is provided with an additive to give a smell upon its leakage from the gas cylinder. Consumers regard energy as a necessary and unspectacular product of which security of supply is important (Fischer, 2008). Energy consumption is not perceived as a coherent field of action; and many unrelated activities like listening to music, cooking meals, working on the computer, washing of clothes and utensils, grinding soaked rice to make batter etc. result in energy consumption as a background activity.

There is a strong linkage between energy consumption and environmental friendliness. The lower the energy consumed, the higher is the concern for environment. As production of energy involves burning of primary non-renewable resources, the process results in emission of gaseous waste to atmosphere which contributes to environmental pollution. Thus, as a part of eco-friendly attitude, energy consumption has to be made optimal. Energy Efficiency implies using less energy to perform the same function and the benefits accruing from adopting energy efficient methods and technology are multi-pronged at consumer level, national level and global level. At consumer level- reduced cost of energy in financial terms, increased competitiveness and productivity levels are the benefits; at national levels- reduced import of crude oil, savings in foreign exchange, conservation of limited resources, improved energy security are the benefits and at global level- reduced GHG and other emissions and maintaining an eco-friendly and sustainable environment are the benefits.

Importance- Performance Analysis (IPA) has been used as an effective technique in evaluating attributes based on the comparative analysis of attribute importance vis-à-vis attribute performance (Martilla J.A. & James V.C., 1977). In importance- performance analysis, attribute importance and attribute performance are both independent variables (Deng W.J., 2008) and they are plotted in an X-Y scatter plot with attribute importance on X-axis and attribute performance on Y-axis. In the scatter plot thus obtained, the mean values of attribute importance and attribute performance are utilised to divide the plot area into four quadrants with attributes in the North-West quadrant (Quadrant I) correspond to “possible overkill” as they are less important, but have high performance. The quadrant on the north-east portion (Quadrant II) consists of those attributes having high importance as well as performance levels, which correspond to “Keep up the good work”. The south-west and the south-east quadrants (Quadrants III & IV respectively) consist of those attributes with low performance. The level of importance for attributes in south-east quadrant (Quadrant IV) is high; the performance level of these attributes has to be improved and these attributes need more attention. The attributes in quadrant IV has a “concentrate here” emphasis. The attributes in quadrant III (South West Quadrant) correspond to “low priority” ones. The critical attributes are those in Quadrants I & IV. Those attributes in quadrant IV are highly important, but the performance levels are less. Hence, these attributes are to be given more care and performance levels of these attributes are to be increased.

No previous study involving fuzzy logic-based importance- performance analysis (IPA) was observed to be made in assessing energy efficiency or environmental protection behavioural attributes in residential buildings upon survey of available literature.

3.**Research Methodology**

The study utilised multi-grade fuzzy logic to generate importance- performance grid and IP analysis. The various attributes for the study were enlisted from the first author's own experience of having worked in a power utility for a long period spanning from 1991 to 2020 and after considering inputs from literature survey. The conceptual model for assessment with two enablers, four criteria and thirty-six attributes were developed as shown in Table 2. Questionnaire- based responses of five experts in the field of energy management were collected personally by the first author on a 10-point scale, after giving a brief description about the attributes, criteria and enablers. Weightages were worked out from the responses of the experts, to obtain the importance

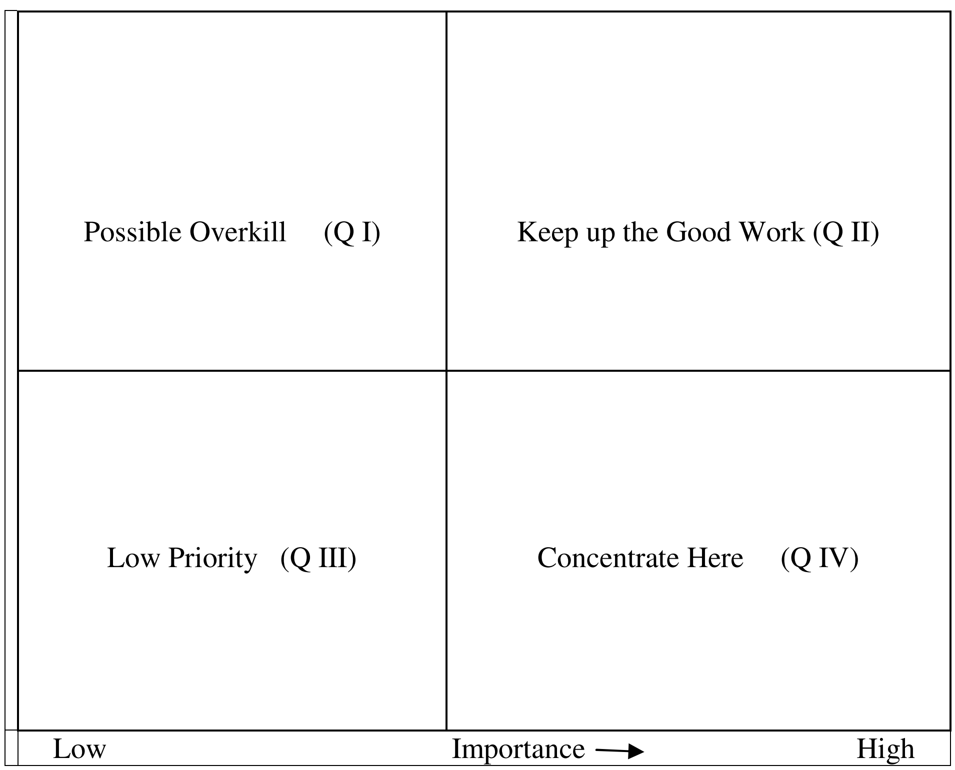

Figure 1: Importance- Performance Grid

against each attribute, criterion and enabler. Ratings were obtained by interviewing five household personnel belonging to XYZ Residents' Association, at a locality situated in Alappuzha Municipality in the state of Kerala and performance levels were assessed from the weightages obtained by interviewing the energy auditor experts.

Mean of the attribute level performance and importance were worked out to obtain mean value of attribute performance and importance. X-Y scatter plot was drawn with importance on X-axis and performance on Y-axis and the mean values were plotted as lines in the importance-performance grid to obtain the quadrants to assess criticality of attributes.

The Energy Efficiency Behavioural (EEB) index (**A**) is computed as the product of overall assessment level of ratings, based on each criteria/ enabler (**R**) and the overall weights (**W**), as given by the experts at primary, secondary and tertiary levels.

$\mathbf{A_i = R_i \times W_i}$

The average value of the index values was taken as the Energy Efficiency Behavioural Index of the cluster formed by the members of the Residents' Association.

$\mathbf{A = (\sum A_i)/n}$;where i = 1,2,…,n. [n is the number of households from whom ratings were sought].

Table 2 : Conceptual Model for Assessment

Enablers	Criteria	Sl No	Attributes
Energy Efficiency	Efficiency Behaviour	A1	Using energy efficient equipment/ gadgets- star rated ones
		A2	Replacing old refrigerators/ air-conditioning units with inefficient compressor
		A3	Replacing light fixtures with more luminous efficiency and low power consumption
		A4	Use of occupancy sensors to turn ON/ OFF lights and fans
		A5	Plugging leakages in water distribution lines in the house
		A6	Frequency of washing laundry
		A7	Using kettle when boiling water instead of electric/gas stoves
		A8	Using energy saving option in the computer system
		A9	Turning OFF television sets with ON/ OFFswitch
		A10	Washing textiles/ dishes only when full machine capacity is attained
		A11	Use of electric iron

		A12	Putting lids on pots during cooking
	Curtailment Behaviour	A13	Avoiding laundry by removing stains and airing
		A14	Avoiding rinsing dishes before putting them to dish washer
		A15	Use of showers instead of bathing tub
		A16	Turning OFF lights and fans when leaving a room
		A17	Covering windows at night using curtains/ blind and uncovering during day time
		A18	Reducing frequency of opening refrigerators
		A19	Cleaning air filters in air-conditioning units occasionally
		A20	Replacing old motor-pump sets in domestic water pump sets
		A21	Rewinding old motor in domestic water pump sets
		A22	Repairing houses in an energy saving direction/ orientation to admit natural light or changing building envelope etc.
		A23	Frequency of use of Electric Iron_ Daily Vs once in a week
Environmental Protection	Altruistic or Eco-Friendly Behaviour	A24	Reduced emission of CO_2 and other Green House Gases
		A25	More restraint on fossil-fuel based energy consumption
		A26	More reliance on Renewable Energy Sources
		A27	Proper disposal of food wastes and other bio-wastes
		A28	Prevention of burning of plastics, thermocoal, rubber etc.
		A29	Use of solar water heaters to source hot water
		A30	Use of solar air-conditioners and inverters
		A31	Use of solar photo-voltaic generation on roof tops
	Fuel Use Curtailment	A32	Less use of hydrocarbon based gasoline/ HSD for cars
		A33	Putting lids on pots during cooking
		A34	Completion of cooking in quick succession to prevent fuel wastage
		A35	Setting standards for emission limits from vehicles and adherence to such standards
		A36	Use of bumps/ dips on roads to regulate speed of vehicles for better fuel efficiency

The scale of assessment of EEB Index was graded into five levels, as per principles of fuzzy determination of the index with value between 8 and 10 representing “Extremely Energy Efficient”, between 6 to 8 representing “Energy Efficient”, between 4 and 6 representing “Fairly Energy Efficient”, between 2 to 4 representing “Energy Inefficient” and between 0 and 2 representing “Extremely Energy Inefficient”.

Energy Efficient Behaviours: Household energy conservation has been identified as a very effective and efficient means of reducing emissions. Recently, the Government of India has stressed the need for bringing in e-mobility by establishing Electric Vehicle Charging Stations

(EVCS) across the length and breadth of the country to shift the transportation sector from crude oil-based gasoline fuel to electricity thereby entailing in savings in foreign exchange by way of savings in import of crude oil. The State Governments have identified nodal agencies to establish EVCS within the geographical boundaries of the states to promote e-mobility. At a later stage, battery swapping stations are also in the offing to reduce the time required for charging electric vehicles in the charging stations.

The various energy efficiency behaviours ask us to spend money or give up comforts and are a trade-off between suffering on one hand and spending on the other (B. Karlin et al, 2014). Energy conservation behaviour varies by frequency of adoption and cost involved. Efficiency Behaviour is infrequent and involves high cost whereas curtailment behaviour is more frequent and low-cost behaviour. Maintenance behaviours are also important, which are essentially inexpensive and non-frequent. Saving of energy is attained by better maintenance of household appliances to improve their performance and efficiency. The dimensions of Energy Conservation behaviour by frequency and cost is better explained by the matrix below, in figure 2.

High Frequency	Curtailment Behaviour	N.A.
Low Frequency	Maintenance Behaviour	Efficiency Behaviour
	Low Cost	High Cost

Figure 2: Dimensions of Energy Conservation Behaviour

Environmental concerns and altruistic eco-friendly behaviour have a great influence on curtailment behaviour than efficiency behaviour. The behaviour of leaving lights/ fans on is a highly visible behaviour and is source of conflict amongst the members of the household, where the enforcing partner runs after the others and keeps the switches off. Efficiency Behaviours often lead to larger energy savings than curtailment behaviour (E. Werff et al, 2018), but the cost involved in engaging in efficiency behaviour is more than that in curtailment behaviour. Adoption of solar panels on roof-tops of houses, modification of houses to admit more sunlight in an energy saving direction or changing the building envelope of the house with a material of less Solar Heat Gain Co-efficient (SHGC) to reduce the R-value of the building etc. are examples of efficiency behaviour. Standards &LabellingProgramme (SLP) of the Bureau of Energy

Efficiency as per the Energy Conservation Act, 2001 is a good indicator to the purchaser when household consumer durables are procured from the market. Star ratings affixed on appliances by accredited laboratories of the Bureau of Energy Efficiency offer decision heuristics for the purchasing consumer to procure energy efficient appliances from the market. Examples of curtailment behaviour can be switching off the television set, instead of being left on standby mode; avoiding laundry by removing stains and airing, especially during winter and rainy seasons; using of showers instead of bath tub; reducing frequency of opening of household refrigerators; reducing frequency of operating electric iron etc. An example of maintenance behaviour can be cleaning air filters in air-conditioning units occasionally to reduce the load on its compressor unit.

Environmental Protection: The driver environmental protection is identified with two criteria in the study viz. altruistic or eco-friendly behaviour and fuel use curtailment. The Intergovernmental Panel for Climate Change (IPCC) proposed to reduce greenhouse gas (GHG) emissions in the energy sector by 90%, compared to 2010 emission levels, between the years 2040 and 2070 (E. Werff et al, 2018). Curtailing energy consumption by domestic users world-wide shall entail in reduction of carbon emission levels to atmosphere, thus helping to attain the recommendations of IPCC. The attributes corresponding to altruistic or eco-friendly behaviour are reduced emission of CO_2 and other GH Gases, more reliance on renewable sources of energy by substituting energy generated by burning fossil-based fuels, prevention of burning of plastics in the home environment to prevent emission of harmful, carcinogenous gases to the atmosphere, use of solar photo-voltaic panels on roof-tops and using them in a grid-tied configuration etc. The attributes for fuel use curtailment are less use of gasoline-based fuels for household cars, more utilisation of electric vehicles instead of IC engine-based cars for domestic transportation etc.

Theoretical Framework for the Study: The theoretical support for the study is provided by the theory of planned behaviour (Ajzen, 2005). As shown in figure 3, the behavioural intention has three antecedents viz. attitudes towards behaviour, subjective norms and degree of perceived behavioural control. Actual behavioural control moderates perceived behavioural control and the manifested behaviour. The theory of planned behaviour proposed by IcekAjzen states that attitude, subjective norms and perceived behavioural control together shape an individual's behavioural intention and behaviour.

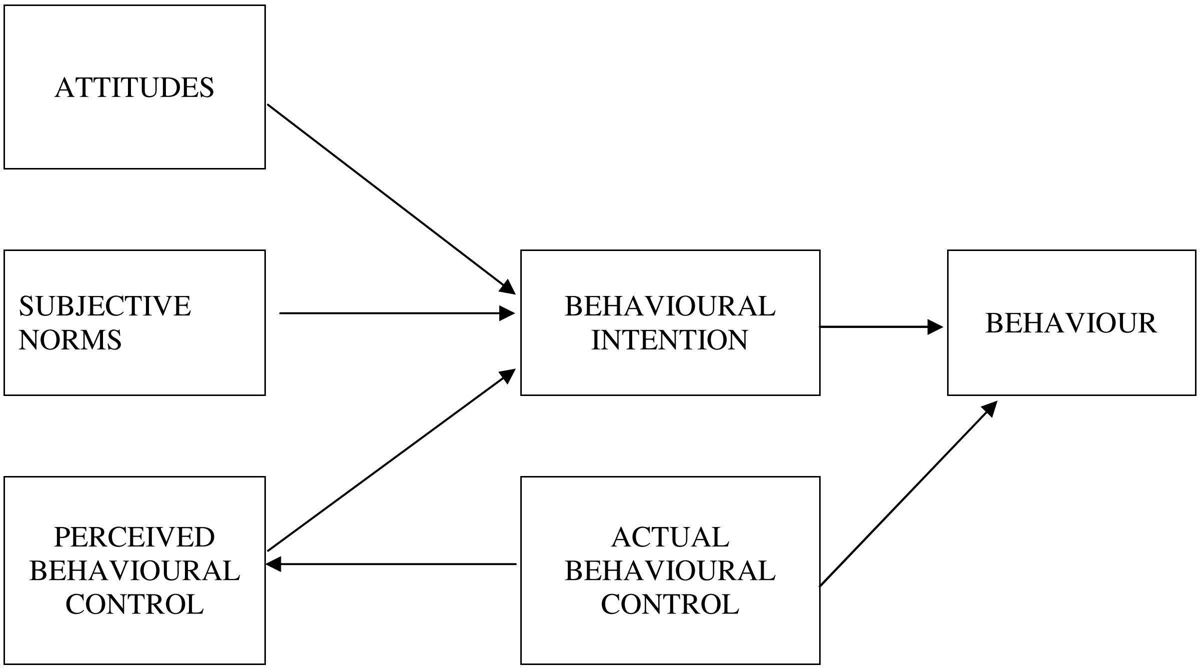

Figure 3: Theory of Planned Behaviour

4. Case Study

The study is made for about 148 households residing in XYZ Residents' Association in Alappuzha Municipal town of the state of Kerala. This locality is situated very near to Vembanad Lake, where there are plenty of tourist boats in operation in the back waters. The place is characterised by the presence of e-coli bacteria in the fresh water lake due to uncontrolled waste disposal from the tourists' boats and the adjoining residential areas. There exist Municipal drinking water supply to the area and the residents boil the water supplied through pipe lines before drinking. Well water exists only in limited old houses in the habitat and the well water also is required to be boiled for drinking. Majority of the households use RO water (purified by Reverse Osmosis) in Alappuzha and adjoining areas, but so far, no mineral deficiency was reported in such users of RO water. The Municipality collects solid wastes generated in the households, which are segregated at source into plastic and food wastes. Plastic waste is collected once in a week after levying a fee of Rs50/- per month per household. Most of the households have pipe composting for effective disposal of bio-degradable and food wastes, but no bio-gas plant exists in any of the household. Solar air-conditioners and solar inverters exist in some of the houses. Rain Water harvesting is necessary in the newly built houses, as per statute and charging occurs to the ground level sump tank. A few of the houses in this habitat has solar PV generating plants on their roof tops and the energy so generated is utilised in the household in grid connected mode.

The case study has been carried out by personally interviewing five prominent decision makers in five households belonging to XYZ Residents' Association and ratings against each attribute were collected. Weights were provided from interviewing well-experienced energy auditors who are energy efficiency practitioners and holding the energy auditor certification from the Bureau of Energy Efficiency. After primary, secondary and tertiary assessment of the ratings with the weights obtained from experts, the overall Energy Efficiency Behavioural index was obtained to be 6.66, which indicates "Energy Efficient", as the value belongs to the range between 6 and 8.

5. Importance- Performance Analysis

Importance- Performance Analysis was done with the attributes with values of importance and performance marked in Table 3. With respect to the mean values of attribute importance and attribute performance, the plot area is divided into four quadrants. Figure 4 shows the IP plot. The critical attributes are located in Quadrants I and IV. The attributes in Quadrant I are A7, A9, A18, A24, A25, A26, A31 and A32. In these eight attributes, the performance levels are higher (above the mean value), even though the importance levels are low. Hence more than required efforts are attributed by households to these eight attributes. The only attribute in Quadrant IV is A8, which is; using energy saving option in the computer system. In modern lap tops and desk tops; energy saving option is automatically invoked after a few minutes or seconds, if no key stroke or mouse movement is made.

Table 3: Importance- Performance Analysis

Sl No	Attributes	Importance	Performance
A1	Using energy efficient equipment/ gadgets- star rated ones	7.4	8.6
A2	Replacing old refrigerators/ air-conditioning units with inefficient compressor	8.6	7.2
A3	Replacing light fixtures with more luminous efficiency and low power consumption	7.6	9.2
A4	Use of occupancy sensors to turn ON/ OFF lights and fans	6.4	3.4
A5	Plugging leakages in water distribution lines in the house	7.6	8.4
A6	Frequency of washing laundry	4.4	5
A7	Using kettle when boiling water instead of electric/gas stoves	7.4	2.4
A8	Using energy saving option in the computer system	6.2	7.4
A9	Turning OFF television sets with ON/ OFFswitch	7.6	6.2
A10	Washing textiles/ dishes only when full machine capacity is	7.6	7.8

	attained		
A11	Use of electric iron	5.2	6.2
A12	Putting lids on pots during cooking	7.6	8.6
A13	Avoiding laundry by removing stains and airing	6.4	1.8
A14	Avoiding rinsing dishes before putting them to dish washer	7	6
A15	Use of showers instead of bathing tub	7.4	9
A16	Turning OFF lights and fans when leaving a room	8.6	8.4
A17	Covering windows at night using curtains/ blind and uncovering during day time	7.6	8.6
A18	Reducing frequency of opening refrigerators	8.2	5.8
A19	Cleaning air filters in air-conditioning units occasionally	8.4	7.8
A20	Replacing old motor-pump sets in domestic water pump sets	7.8	8
A21	Rewinding old motor in domestic water pump sets	2.2	3.4
A22	Repairing houses in an energy saving direction/ orientation to admit natural light or changing building envelope etc.	4.8	5.2
A23	Frequency of use of Electric Iron_ Daily Vs once in a week	8	7.2
A24	Reduced emission of CO2 and other Green House Gases	8.2	4
A25	More restraint on fossil-fuel based energy consumption	7.4	5.6
A26	More reliance on Renewable Energy Sources	8	5.2
A27	Proper disposal of food wastes and other bio-wastes	7.2	7.6
A28	Prevention of burning of plastics, thermocoal, rubber etc.	8	9.6
A29	Use of solar water heaters to source hot water	7	5.8
A30	Use of solar air-conditioners and inverters	6.8	3.2
A31	Use of solar photo-voltaic generation on roof tops	7.4	2.6
A32	Less use of hydrocarbon based gasoline/ HSD for cars	7.4	5.4
A33	Putting lids on pots during cooking	7.4	9.6
A34	Completion of cooking in quick succession to prevent fuel wastage	7.2	9
A35	Setting standards for emission limits from vehicles and adherence to such standards	7.4	8
A36	Use of bumps/ dips on roads to regulate speed of vehicles for better fuel efficiency	3	2.6

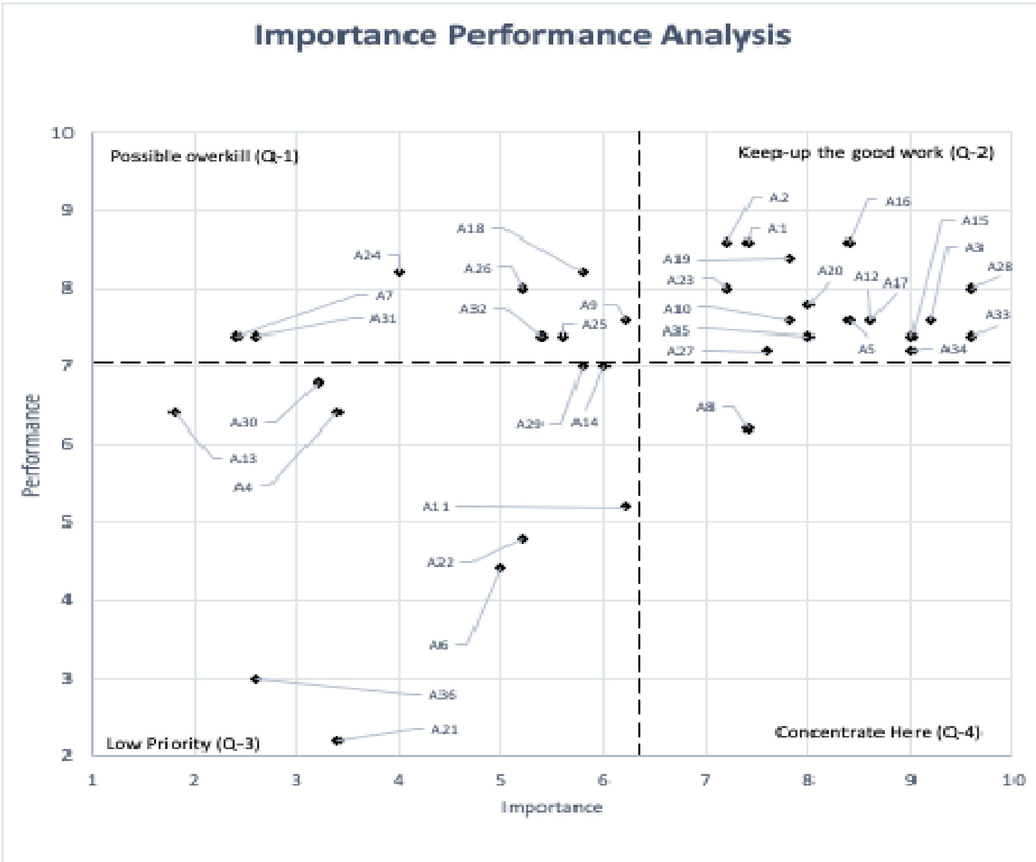

Figure 4: Importance- Performance Plot

6. Conclusion

Out of the 36 nos of Attributes in the study, 23 nos correspond to Energy Efficiency behavioural attributes and the remaining 13 nos correspond to behaviours contributing to Environmental Protection. On analysis of the attributes from the IP plot, it was observed that eight numbers of attributes viz. A7, A9, A18, A24, A25, A26, A31 and A32 are grouped under "Possible overkill", in Quadrant I; which means that the performance levels of these eight attributes are far more than the required values and hence the positive aspects of these behavioural attributes could be unlearnt without causing any concern to the Energy Efficiency behaviours and Environmental Protection behaviours of the members of the Residents' Association under study. Actually, the attribute A8; which is the only attribute emerged as part of the study under Quadrant IV corresponding to "concentrate here" does not hold much significance as the technology available in the recent times in the desk tops and laptops takes care of the beneficial aspects of Energy Efficiency behaviour.

There are 17 attributes in quadrant II corresponding to "Keep up the good work" viz., A1, A2, A3, A5, A10, A12, A15, A16, A17, A19, A20, A23, A27, A28, A33, A34 and A35. These behavioural attributes contribute generously to achieving Energy Efficiency and Environmental Protection. These behavioural attributes can be inculcated amongst the members of XYZ Residents' Association for the benefit of the society, nation and the world.

The ten numbers of low priority behavioural attributes viz., A4, A6, A11, A13, A14, A21, A22, A29, A30 and A36 are those in quadrant III of the IP plot and they represent those attributes with low importance and performance levels. Deploying occupancy sensors to turn ON/ OFF lights and fans, repairing houses in an energy saving directions or changing building envelope etc. are very costly propositions to be economically viable for energy efficiency in the domestic environment. The behavioural attributes A21 and A36 are negative behaviours and do not contribute to achieving energy efficiency and environmental protection respectively.

Reducing energy intensity, wastages in energy; utilising energy with a conservative mentality coupled with lower dependence on fossil-based fuels result from higher adoption of energy efficiency behaviours which in turn contribute to environmental protection. The learning from this study can be replicated to other communities in the region with the same socio-cultural norms and extended to promote energy efficiency and environmental protection behaviours for the benefit of the nation and the world.

7. Directions for Future Research

In the current study, the energy efficiency behaviour and environmental behaviour of a Residents' Association, located in Alappuzha Municipality in the state of Kerala was studied and the Energy Efficiency Behavioural (EEB) index was assessed, using multi-grade fuzzy. The focus was obviously on the household consumers of energy. In other classes of consumers of energy viz. commercial, industrial and agricultural sectors; study could be conducted with different sets of attributes concerning consumers' behaviour in the related sectors using multi-grade fuzzy. Also, the RO water usage for drinking and cooking purposes in Alappuzha Municipality area has a potential to restrict essential minerals in normal mineral water to the human body and this behaviour may cause health hazards due to deficiency of those essential minerals. No research has so far been undertaken to assess the possible deficiencies in the human body due to use of RO water.

Development of the state-of-the-art technology in grid management and metering gave an impetus to area of research related to efficiency behaviours in using the secondary energy source viz. electricity. In smart grid environment, each of the devices in the system is enabled with a sensor and could be addressed and the decision heuristics to switch on a device is taken based on the availability of power, cost of energy per unit at a given slot of time etc. Hence the not-so-important loads could be switched on when the tariff is the least in a time-of-day scenario. The study could also be extended in a smart grid environment enabled with advanced metering infrastructure.

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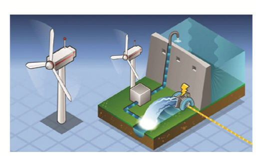
Artificial Intelligence (AI) is a technology that is transforming every walk of life. It is a wide-ranging tool that enables people to rethink how we integrate information, analyze data, and use the resulting insights to improve decision making.

AI is not a futuristic vision, but rather something that is here today and being integrated with and deployed into a variety of sectors. This includes fields such as engineering, technology ,finance, national security, health care, criminal justice, transportation, and smart cities. AI is making an impact on the world and augmenting human capabilities in significant ways in recent days



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